

DECLARATION OF THE RECORD OF DECISION

SITE NAME AND LOCATION

Naval Submarine Base, Bangor
Operable Unit 6
Silverdale, Washington

STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected action for Operable Unit 6 (OU 6) at the Naval Submarine Base (SUBASE), Bangor in Silverdale, Washington, chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). OU 6 consists of Site D, a former ordnance disposal area. This decision is based on the administrative record for this site.

The lead agency for this decision is the United States Navy. The United States Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology) have participated in scoping the site investigations and in evaluating alternatives for remedial action. The EPA and Ecology concur with the selected remedy.

ASSESSMENT OF THE SITE

Actual or threatened releases of hazardous substances from Site D, if not addressed by implementing the response action selected in this Record of Decision, may present an imminent and substantial endangerment to public health, welfare, or the environment.

DESCRIPTION OF THE SELECTED REMEDY

The selected remedy at Site D will address the threat posed by treatment of ordnance-contaminated soils. Soil containing ordnance compounds at concentrations greater than established cleanup levels will be excavated and treated by on-base composting, an innovative technology. Confirmation sampling will be done to ensure that cleanup levels have been attained. Once cleanup levels are achieved, the composted soils will be returned to the excavation, and the area will be regraded and revegetated.

DECLARATION

The selected remedy is protective of human health and the environment, is in compliance with federal and state requirements that are legally applicable or relevant and appropriate to the remedial action, and is cost effective. This remedy uses permanent on-site solutions and alternative treatment or resource recovery technologies to the maximum extent practicable, and satisfies the statutory preference for remedies that employ treatment that reduces toxicity, mobility, or volume as a principal element.

Signature sheet for the foregoing SUBASE, Bangor Operable Unit 6, Remedial Action. Record of Decision between the United States Navy and the United States Environmental Protection Agency, with concurrence by the Washington State Department of Ecology.



Captain Ernest R. Lockwood
SUBASE, Bangor Commanding Officer
United States Navy

9/21/94

Date

Signature sheet for the foregoing SUBASE, Bangor Operable Unit 6, Remedial Action, Record of Decision between the United States Navy and the United States Environmental Protection Agency, with concurrence by the Washington State Department of Ecology.

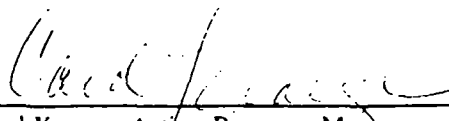
Chuck Clarke

Chuck Clarke
Regional Administrator, Region 10
United States Environmental Protection Agency

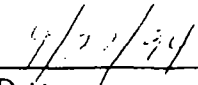
8/8/94

Date

Signature sheet for the foregoing SUBASE, Bangor Operable Unit 6, Remedial Action, Record of Decision between the United States Navy and the United States Environmental Protection Agency, with concurrence by the Washington State Department of Ecology.



Carol Kraege, Acting Program Manager
Toxics Cleanup Program
Washington State Department of Ecology



Date

CONTENTS

	<u>Page</u>
ABBREVIATIONS AND ACRONYMS	vii
1.0 INTRODUCTION	1
2.0 SITE NAME, LOCATION, AND DESCRIPTION	1
3.0 SITE HISTORY	3
4.0 HIGHLIGHTS OF COMMUNITY PARTICIPATION	5
5.0 SCOPE AND ROLE OF OPERABLE UNITS	6
6.0 SUMMARY OF SITE CHARACTERISTICS	7
6.1 SURFACE WATER HYDROLOGY	7
6.2 SITE HYDROGEOLOGY	7
6.2.1 Vashon Recessional Outwash	7
6.2.2 Vashon Till	11
6.2.3 Vashon Advance Outwash	13
6.2.4 Kitsap Formation	13
6.3 NATURE AND EXTENT OF CONTAMINATION	15
6.3.1 Surface Water	15
6.3.2 Freshwater Sediments	19
6.3.3 Surface Soils	20
6.3.4 Subsurface Soils	26
6.3.5 Groundwater	31
6.4 PHYSICAL AND CHEMICAL BEHAVIOR OF ORDNANCE COMPOUNDS	37
7.0 SUMMARY OF SITE RISKS	40
7.1 HUMAN HEALTH RISK ASSESSMENT AND CHARACTERIZATION	40
7.2 ECOLOGICAL RISK ASSESSMENT	46
7.3 UNCERTAINTY ANALYSIS	48
7.3.1 Data Evaluation	50

7.3.2	Exposure Assessment	50
7.3.3	Toxicity Assessment	52
7.3.4	Risk Characterization	54
8.0	REMEDIAL ACTION OBJECTIVES	56
8.1	SOILS	56
8.2	SURFACE WATER	60
8.3	GROUNDWATER	62
8.3.1	Perched Aquifer	62
8.3.2	Shallow Aquifer	62
9.0	DESCRIPTION OF ALTERNATIVES	63
9.1	ALTERNATIVE 1: NO ACTION	63
9.2	ALTERNATIVE 2: INCINERATION	64
9.2.1	Excavation	64
9.2.2	Stockpiling	65
9.2.3	Process Description	65
9.2.4	Operating Parameters	65
9.2.5	Incineration ARARs	66
9.2.6	Monitoring and Review	67
9.2.7	Land-Use Restrictions	68
9.3	ALTERNATIVE 3: COMPOSTING	68
9.3.1	Excavation	68
9.3.2	Stockpiling	68
9.3.3	Process Description	68
9.3.4	Operating Parameters	70
9.3.5	Composting ARARs	71
9.3.6	Monitoring and Review	72
9.3.7	Land-Use Restrictions	72
10.0	COMPARATIVE ANALYSIS OF ALTERNATIVES	73
10.1	OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	74
10.1.1	Alternative 1	74
10.1.2	Alternative 2	74
10.1.3	Alternative 3	75
10.2	COMPLIANCE WITH ARARs	75
10.2.1	Alternative 1	75

FIGURES

1	Site Location and Geographic Setting	2
2	Site D	4
3	Site D, Surficial Geology, Well Locations/Cross Sections	8
4	Site D, Geologic Cross Section A-A'	9
5	Site D, Geologic Cross Sections B-B' and C-C'	10
6	Potentiometric Contour Map, Perched Aquifer, August 1992	12
7	Potentiometric Contour Map, Shallow Aquifer, August 1992	14
8	Site D, Surface Water and Sediment Sampling Locations	16
9	Site D, Surface Soil Laboratory Confirmation Samples	23
10	Site D, Soil Boring Locations	27
11	Site D, Monitoring Well Locations	28
12	Areas Targeted for Remediation	57

TABLES

1	Chemicals Detected in Surface Water	17
2	Chemicals Detected in Freshwater Sediments	21
3	Chemicals Detected in Surface Soils	24
4	Chemicals Detected in Subsurface Soils From the Vashon Recessional Outwash	29
5	Chemicals Detected in Subsurface Soils From the Vashon Till	32
6	Chemicals Detected in Subsurface Soils From the Vashon Advance Outwash	33
7	Chemicals Detected in Subsurface Soils From the Kitsap Formation	34
8	Chemicals Detected in Groundwater From the Perched Aquifer	35
9	Chemicals Detected in Groundwater From the Shallow Aquifer	38
10	Reasonable Maximum Exposure Concentrations for Chemicals of Potential Concern—Human Health Evaluation	42
11	Total Hazard Index and Cancer Risk for Site D for Future Resident	44
12	Total Hazard Index and Cancer Risk for Naturally Occurring Inorganic Compounds Detected in Area Background Samples	45
13	Total Incremental Hazard Index and Cancer Risk for Site D	45
14	Chemicals of Potential Concern—Ecological Evaluation	47
15	Hazard Quotients Greater Than 1.0 for Ecological Receptors	48
16	Summary of Uncertainties in the Risk Assessment Approach and Site-Specific Characteristics	49

SUBASE, BANGOR OPERABLE UNIT 6
U.S. Navy CLEAN Contract
Engineering Field Activity, Northwest
Contract No. N62474-89-D-9295
CTO 0039

Record of Decision
Date: 07/19/94
Page vi

17	Soil Treatment Levels for 2,4,6-Trinitrotoluene and Related Ordnance Compounds	59
18	Cost Comparison of Remedial Action Alternatives	82

ABBREVIATIONS AND ACRONYMS

ARAR	applicable or relevant and appropriate requirement
AWQC	Ambient Water Quality Criteria
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
COPC	chemical of potential concern
CSF	carcinogenic slope factor
DSW	surface water/sediment sampling locations
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
FFA	Federal Facility Agreement
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
MAIV	mechanically agitated in-vessel
MCL	maximum contaminant level
MCLG	maximum contaminant level goals
mg/kg	milligrams per kilogram
MTCA	Model Toxics Control Act (Washington State)
MW	monitoring well
N/A	not available
NAD	Naval Ammunition Depot
Navy	United States Navy
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
NTS	Naval Torpedo Station
NWP	Nationwide Permit
OSHA	Occupational Health and Safety Administration
OU	Operable Unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
Qk	Kitsap Formation
Qva	Vashon Advance Outwash
Qvr	Vashon Recessional Outwash
Qvt	Vashon Till

SUBASE, BANGOR OPERABLE UNIT 6
U.S. Navy CLEAN Contract
Engineering Field Activity, Northwest
Contract No. N62474-89-D-9295
CTO 0039

Record of Decision
Date: 07/19/94
Page viii

RAO	remedial action objective
RBSC	risk-based screening concentration
RCRA	Resource Conservation and Recovery Act
RDX	Royal Demolition Explosive (cyclonite or hexahydro-1,3,5-trinitro-1,3,5-triazine)
RfD	reference dose
RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act of 1986
SUBASE	submarine base
TBC	to be considered
TCLP	Toxicity Characteristics Leachate Procedure
TNT	2,4,6-trinitrotoluene
UCL	upper confidence limit
VOC	volatile organic compound
WISHA	Washington Industrial Safety and Health Administration
$\mu\text{g}/\text{kg}$	micrograms per kilogram
$\mu\text{g}/\text{L}$	micrograms per liter

DECISION SUMMARY

1.0 INTRODUCTION

It is the policy of the United States Navy (Navy) to address contamination at its installations, under the Defense Environmental Restoration Program, in a manner consistent with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA).

2.0 SITE NAME, LOCATION, AND DESCRIPTION

Naval Submarine Base (SUBASE), Bangor is situated on Hood Canal, in Kitsap County, Washington, approximately 10 miles north of Bremerton (Figure 1). Land surrounding SUBASE, Bangor is generally undeveloped, supporting limited residential uses. Naval activities began at Bangor on June 4, 1944, when the United States Naval Magazine, Bangor was officially established as a Pacific shipment point for ordnance. When World War II ended, the Bangor Naval Complex became available for the storage of ordnance.

On July 22, 1987, Site A was listed on the United States Environmental Protection Agency's (EPA) National Priorities List (NPL) of hazardous waste sites. On August 30, 1990, the remainder of the SUBASE, Bangor facility was listed on the NPL.

On January 29, 1990, a cooperative three-party Federal Facility Agreement (FFA) was signed by the Navy, EPA, and the Washington State Department of Ecology (Ecology) for study and cleanup of possible contamination on the SUBASE, Bangor property. Operable Unit 6 (OU 6) consists of Site D, 1 of the 19 sites that are included in the SUBASE, Bangor FFA.

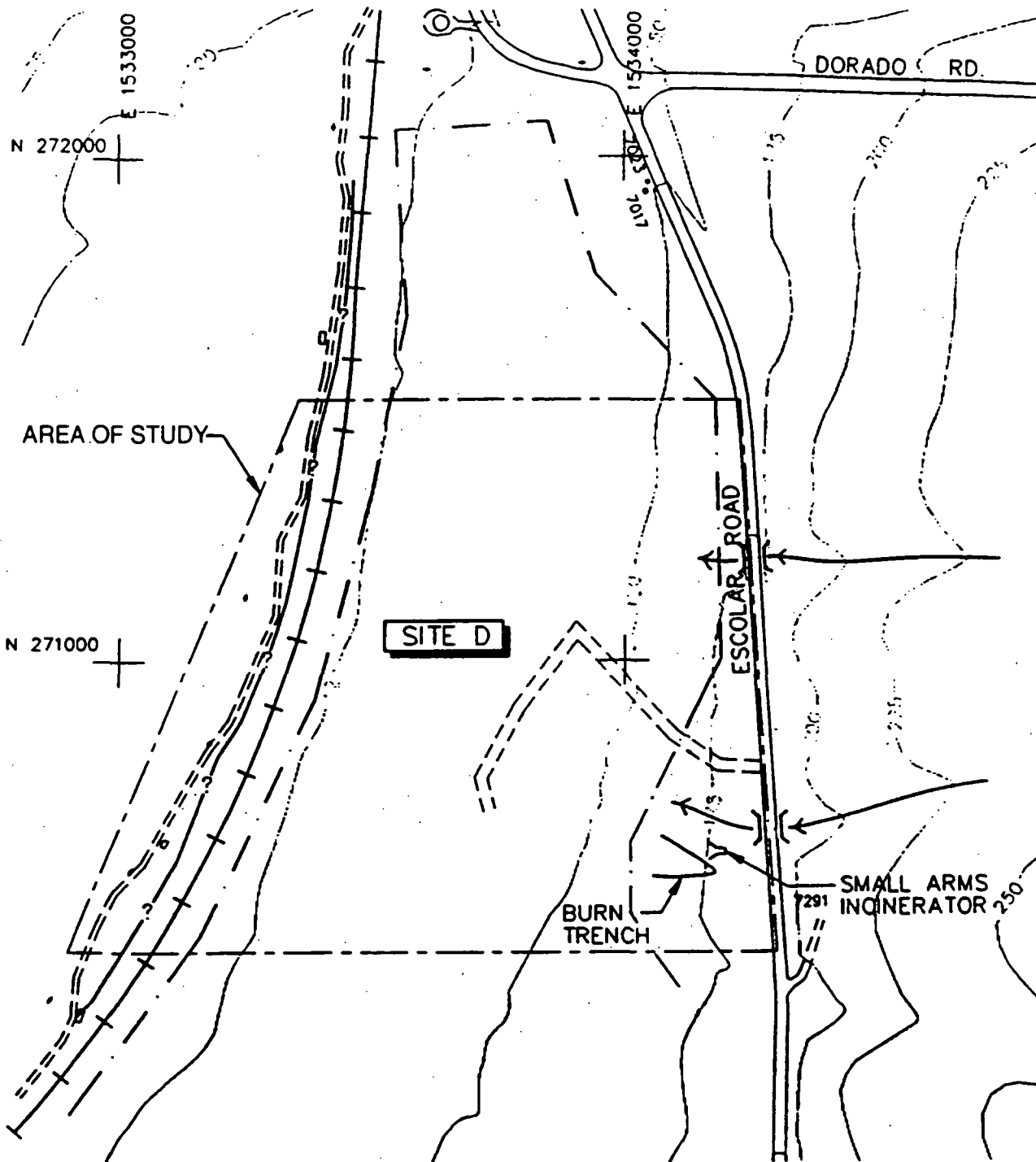
3.0 SITE HISTORY

Site D is a former ordnance disposal area (Figure 2). The primary disposal practice consisted of burning and detonating ordnance on the site. Some material was also buried. Site D served as the principal area for burning and detonating ordnance at SUBASE, Bangor from 1946 until 1963, when these activities were transferred to Site A. The area was used sporadically for ordnance disposal until approximately 1965. Waste disposal areas at Site D included a small arms incinerator, a burn trench, and smaller burn areas or mounds.

Based on historical aerial photos, the dimensions of the suspected burn trench are estimated to be 15 to 20 feet by 200 feet. The depth of the trench, although unknown, is suspected to be less than 10 feet because of the presence of groundwater in a perched aquifer. The trench was located during the remedial investigation (RI) using geophysical techniques.

Between 1944 and 1957, explosive D (ammonium picrate) sludge from the steam cleaning of projectiles at other areas was transferred to Site D for disposal (U.S. Navy 1983). This practice reportedly was most active for a 6-year period in the late 1940s and early 1950s. Records fail to clarify whether this material was burned or buried.

Previous site investigations, including personal interviews, indicated that photo flash bombs and ammonium nitrate blocks were detonated at Site D (Hart Crowser 1989). Other items that were burned or detonated may have included smokeless powder, black powder, rocket propellant, white phosphorous shells, compound B (2,4,6-trinitrotoluene [TNT] and Royal Demolition Explosive [RDX]), amatol (ammonia nitrate and 2,4,6-trinitrotoluene), and ordnance wastes containing 2,4,6-trinitrotoluene and RDX. Propulsion missile grains from approximately 600 obsolete rocket motors were reportedly destroyed in trenches on the site. The missile grains were ignited with smokeless powder and, upon completion of burning, the trenches were soaked with water. In conjunction with these activities, a small arms incinerator was in operation prior to 1964 (U.S. Navy 1983). The quantities of wastes deposited at Site D could not be determined from available data (Hart Crowser 1989).



LEGEND:

RAILROAD
 PAVED ROAD
 DIRT ROAD
 EPHEMERAL STREAM

AREA OF STUDY
 APPROXIMATE WETLAND BOUNDARY



0 150' 300'

CLEAN
COMPREHENSIVE LONG-
TERM ENVIRONMENTAL
ACTION NAVY

Figure 2
Site D

CTO 0039
OPERABLE UNIT 6
SUBASE, Bangor
ROD

4.0 HIGHLIGHTS OF COMMUNITY PARTICIPATION

The SUBASE, Bangor Community Relations Plan for the remedial activity on the base is available for review at the information repositories. Community relations activities have established communication among citizens living near the site, the Navy, EPA, and Ecology. The actions taken to satisfy the requirements of the federal law (cited below) have also provided a forum for citizen involvement and input to the remedial action decision.

The specific requirements for public participation pursuant to CERCLA Section 113(k)(2)(b) and Section 117(a) as in 42 USC 9617(2), as amended by SARA, include releasing the proposed plan for remedial action to the public. The proposed plan for remedial action was placed in the administrative record and information repositories.

The administrative record is on file in the following location:

Engineering Field Activity, Northwest
Naval Facility Command
1040 N.E. Hostmark Street
Olympic Place II
Poulsbo, Washington
(206) 396-5984

The information repositories are in the following locations:

Central Kitsap Regional Library
1301 Sylvan Way
Bremerton, Washington
(206) 377-7601

SUBASE, Bangor Branch Library
Naval Submarine Base, Bangor
Bangor, Washington
(206) 779-9274
(Base access is required.)

A fact sheet was issued in May 1992 that discussed the historical activities at OU 6 and the proposed investigation. The proposed plan for remedial action was issued in a fact sheet format recommended by EPA guidance and was mailed to all known interested parties in January 1994. Notice of the availability of the proposed plan and notice of a public meeting on the proposed plan and public comment period were published in *The Sun* (Bremerton) on January 9, 1994, and *The Trident Tides* on January 14, 1994. A public comment period was held from January 9, 1994, to February 8, 1994. A public meeting was held on January 27, 1994, at the Olympic View Community Club in Silverdale, Washington. A total of 27 people attended.

Two public comments were received by the Navy concerning the proposed plan for remedial action at OU 6. The comments, which were submitted at the public meeting, are summarized in the Responsiveness Summary (Attachment 1).

5.0 SCOPE AND ROLE OF OPERABLE UNITS

This Record of Decision (ROD) addresses all of OU 6. OU 6 consists of Site D, 1 of the 19 sites that are listed in the SUBASE, Bangor FFA. The sites were organized into seven operable units based on geographic location, suspected contamination, or other factors. A separate study is being conducted for each operable unit to determine appropriate cleanup actions. The baseline risk assessment in the remedial investigation/feasibility study (RI/FS) (URS 1993) indicated that the chemicals detected at Site D posed potential risks to human health and the environment.

Composting, the selected remedy at Site D, is a measure to minimize human health and ecological risks associated with soil contamination. This action includes soil treatment to destroy soil contaminants. Surface water and groundwater will be monitored to ensure that conditions at the site after soil treatment are protective of human health and the environment.

6.0 SUMMARY OF SITE CHARACTERISTICS

6.1 SURFACE WATER HYDROLOGY

Much of Site D is seasonally wet; the lower portion of the site contains standing water during the wet season. Surface water becomes impounded in the topographically low area between the general slope of the site and the railroad grade and flows off site in an ephemeral drainage. Groundwater seepage also occurs in this area along a broad seepage front where the perched aquifer, contained within the recessional outwash, is truncated. Surface water enters the site from two ephemeral drainages and one perennial stream and flows into the poorly drained, seasonally wet western portion of the site. Runoff ultimately drains into Devil's Hole Lake to the northwest.

6.2 SITE HYDROGEOLOGY

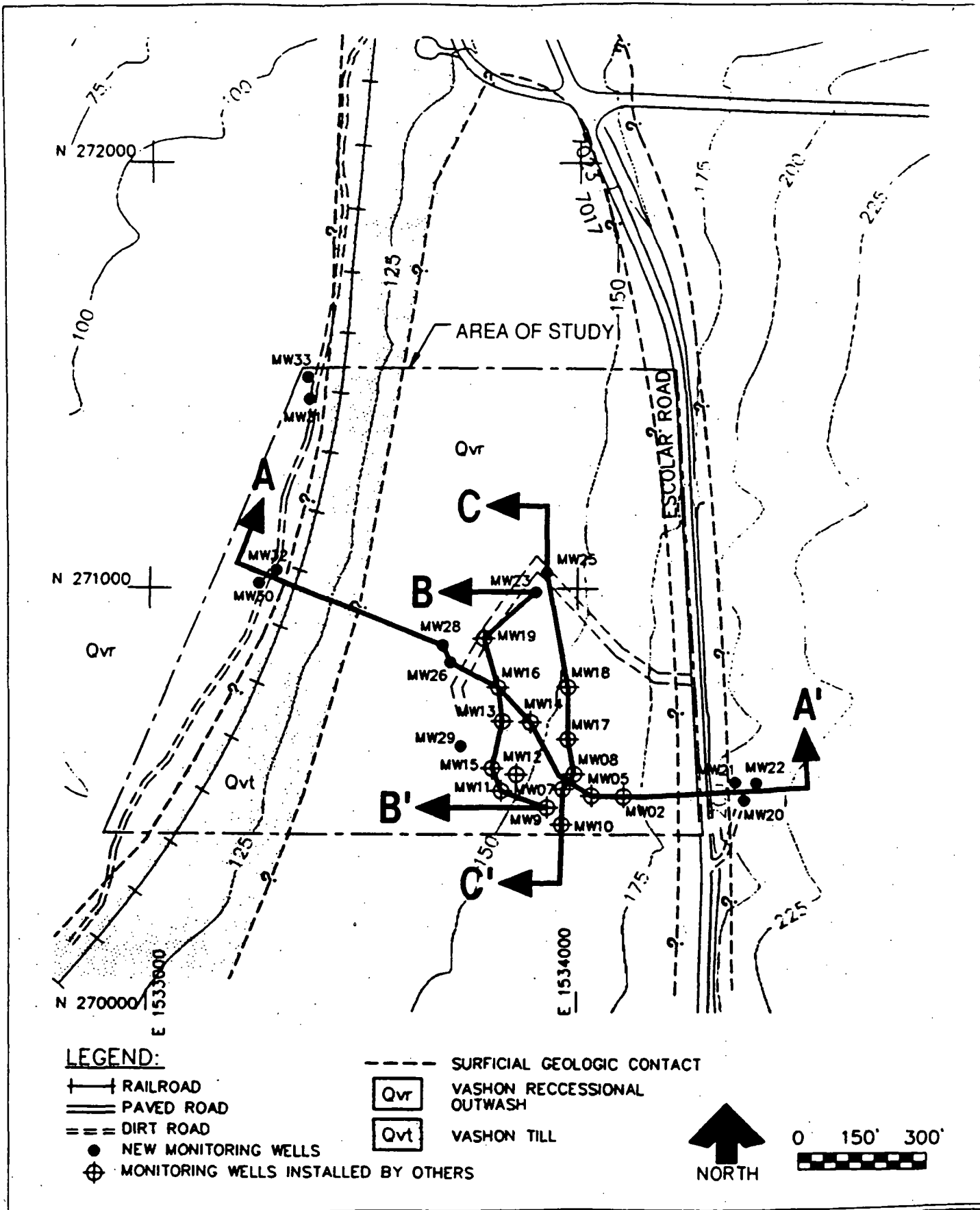
Four geologic units were identified during drilling at Site D. These units are the Vashon Recessional Outwash, Vashon Till, Vashon Advance Outwash, and Kitsap Formation. The designation "Vashon" is used to distinguish those units deposited during the most recent glacial advance. The Kitsap Formation was deposited during an interglacial period and is distinguished by its massive thickness of silt with high organic content.

The aquifers identified in the study area of Site D during RI/FS activities are the perched and the shallow aquifers. The aquitards identified in the study area are the Vashon Till, between the perched and shallow aquifers, and the Kitsap Formation, which underlies the shallow aquifer.

The surficial geology and well locations at Site D are shown in Figure 3. Figures 4 and 5 present geologic cross-sections of Site D.

6.2.1 Vashon Recessional Outwash

The Vashon Recessional Outwash (Qvr), the uppermost geologic unit at Site D, contains a perched aquifer. This unit ranges in thickness from 0 feet to approximately 30 feet at Site D and is deposited over the surface of the Vashon Till. The Vashon Recessional Outwash is typically a reddish-brown sandy gravel with varying amount of silt, clay, and sand.



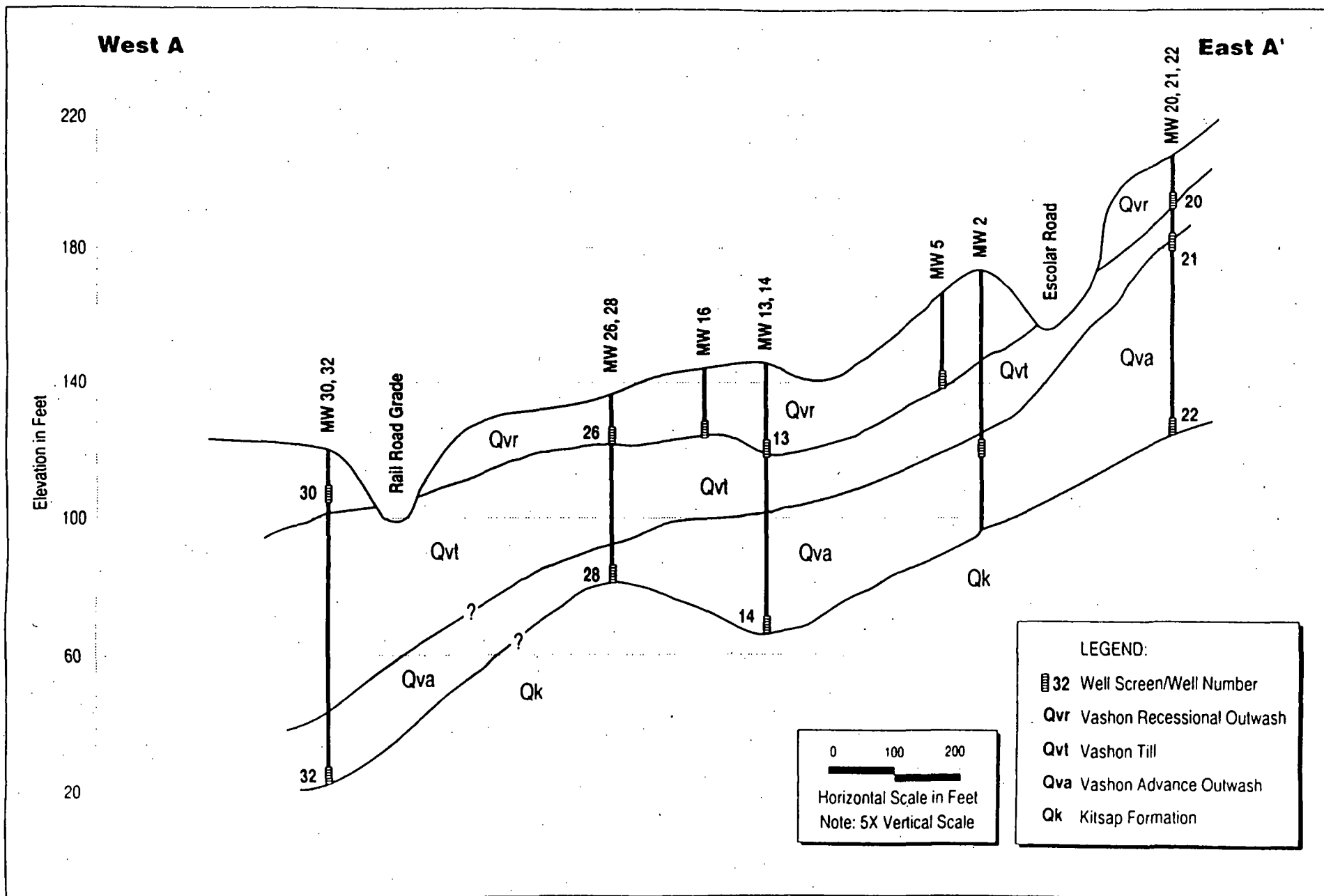
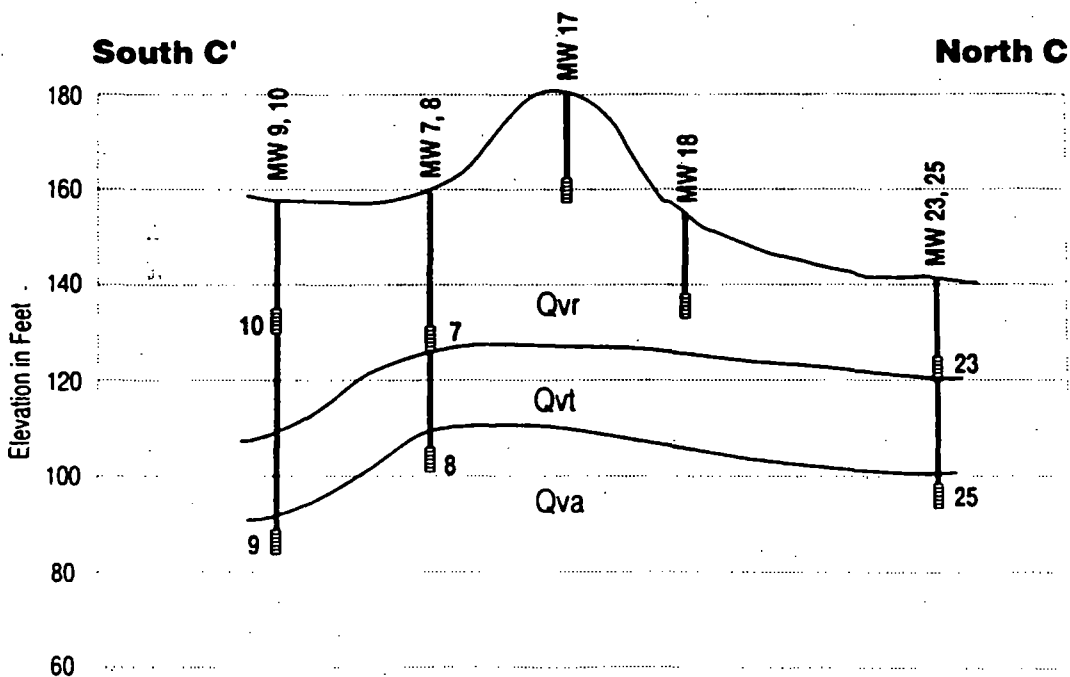
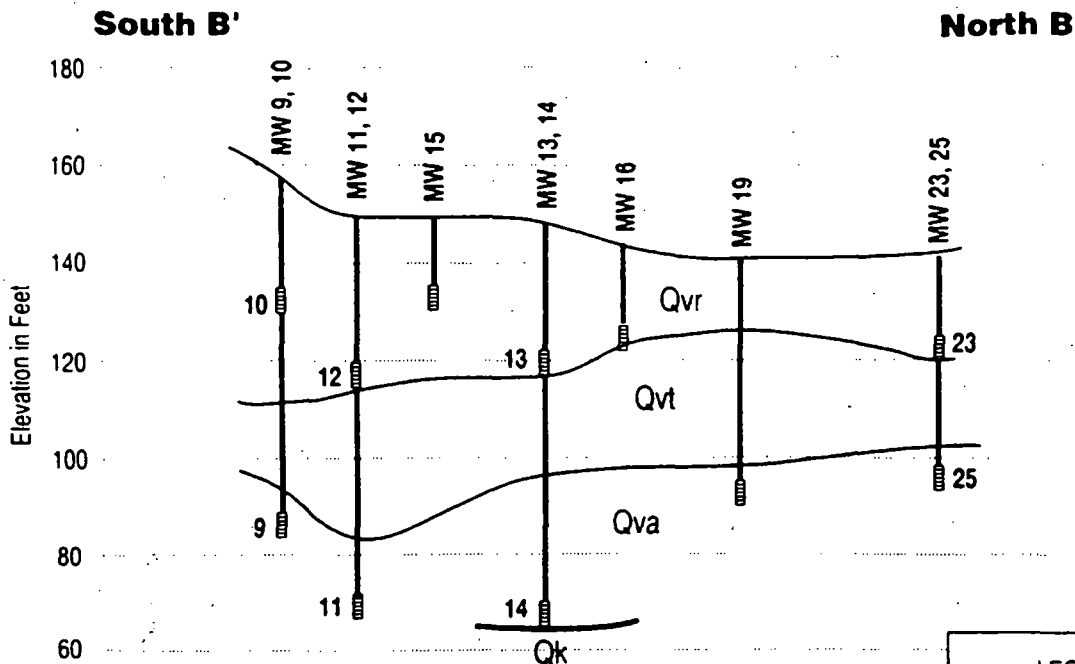


Figure 4
Site D
Geologic Cross Section A-A'



Water levels measured within the perched aquifer were often at or near the ground surface. The aquifer flows in a west to northwesterly direction. Potentiometric contours for August 1992 (shown in Figure 6) are a typical representation of the perched aquifer groundwater characteristics. Groundwater gradients in the perched aquifer range from about 0.04 ft/ft to 0.20 ft/ft. Seasonal variations of the perched aquifer water levels in individual wells ranged from less than 1 foot to almost 9 feet.

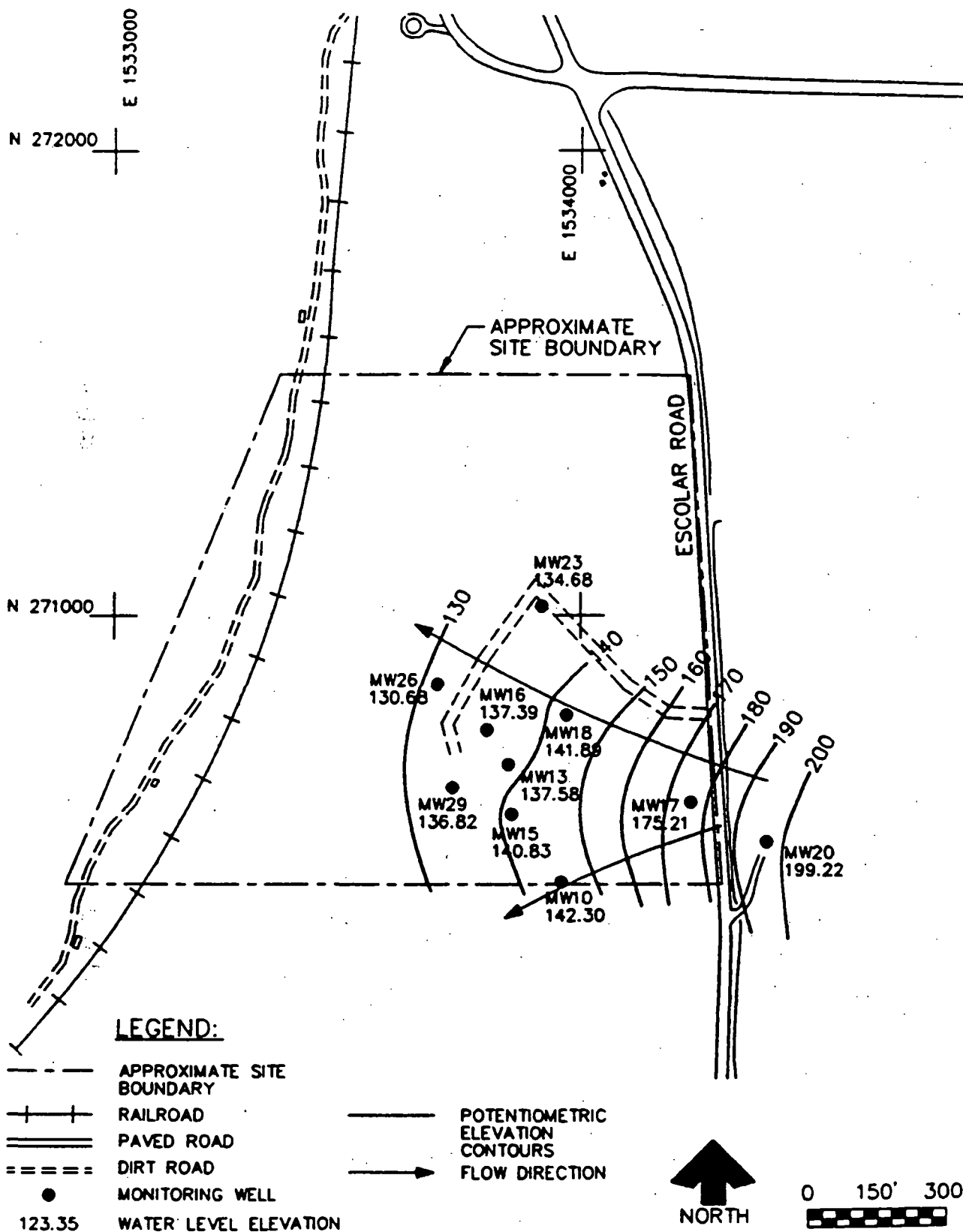
The perched aquifer at Site D is unconfined. The unit thins to the west portion of the site, creating a marshy area in the western portion of Site D. The measured hydraulic conductivity in the perched aquifer ranges from 1.4×10^{-4} cm/sec to 6.2×10^{-3} cm/sec. Grain size analysis indicated that the soil from the perched aquifer consists predominantly of a silty sand.

Using an average gradient and hydraulic conductivity within the perched aquifer at Site D, an average groundwater velocity of about 1.46 feet per day was estimated. Well yields in excess of 0.5 gallons per minute could be sustained for a short period. However, because of the perched nature of the aquifer and proximity to the discharge area, this aquifer could not be depended on to provide a reliable water supply and should not be considered a potential drinking water source. Long-term pumping could induce infiltration of surface water from the wetland into the aquifer.

6.2.2 Vashon Till

The Vashon Till (Qvt) is approximately 10 feet thick at Site D and extends to nearly 60 feet thick near the western portion of the area of study. The Qvt encountered at Site D consists of a blue-gray, very dense, poorly sorted mixture of sand, gravel, silt, and clay. Sand lenses are present within the Qvt but are thin and discontinuous. This unit oxidizes to an orange-brown color near the surface.

The hydrologic characteristics of the Qvt vary considerably throughout SUBASE, Bangor. Permeabilities range from a low of 0.003 feet per day (1×10^{-6} cm/sec) to a high of 0.08 feet per day (3.0×10^{-5} cm/sec). The Qvt is designated as an aquitard. At Site D, the Qvt occurs primarily as a low-permeability unit impeding downward flow of water.



6.2.3 Vashon Advance Outwash

The Vashon Advance Outwash (Qva) at Site D is a light gray, fine silty sand with gravel. This formation ranges in thickness from 10 to 60 feet at Site D. The Qva contains the shallow aquifer at Site D.

Horizontal gradients ranged from 0.05 ft/ft to 0.18 ft/ft for the shallow aquifer. The range in groundwater gradients is the result of both topographic changes across the site and seasonal variations during the observation period of October 1991 through August 1992. Potentiometric contours for August 1992 are illustrated in Figure 7. Groundwater flows in a west to northwesterly direction.

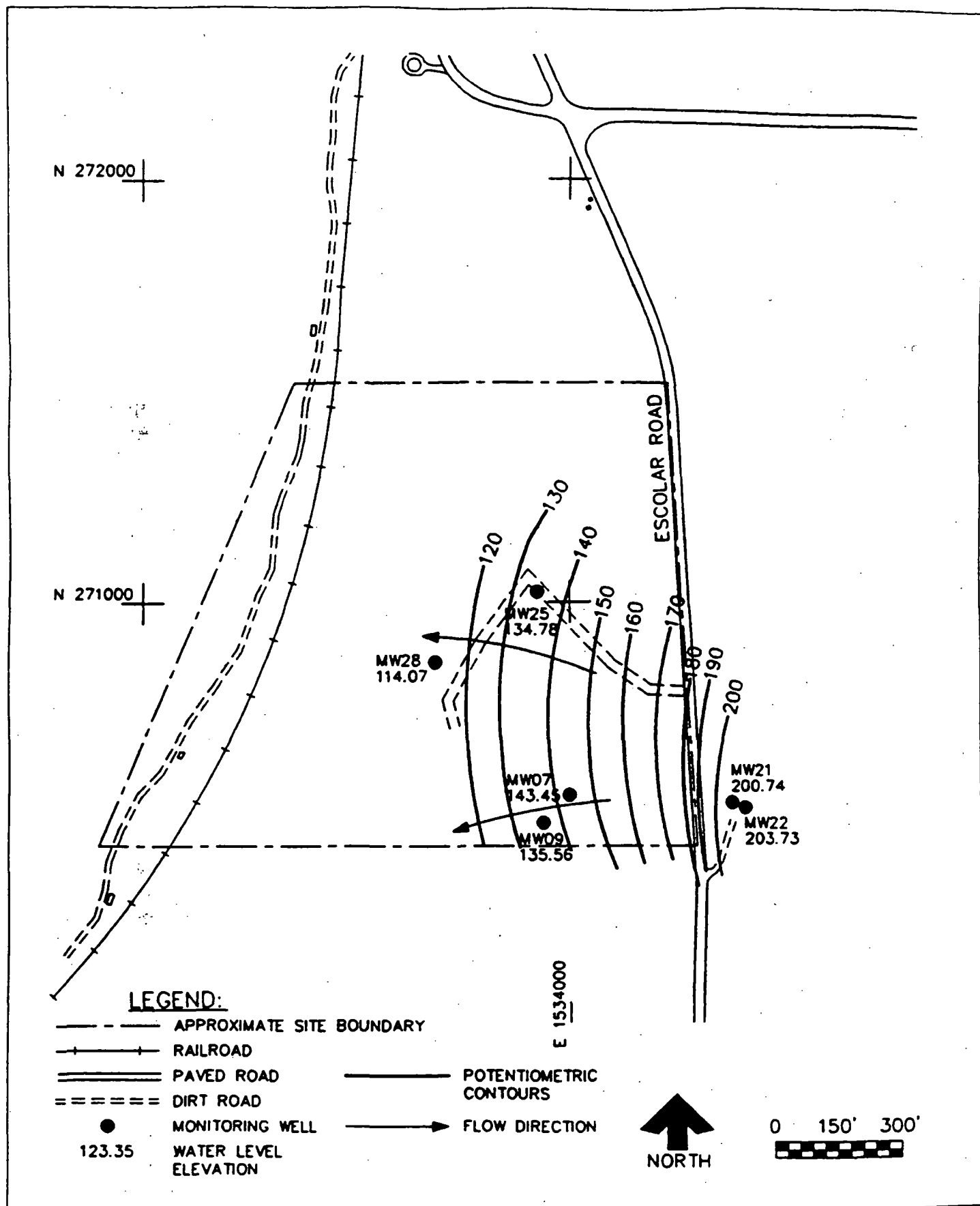
Water levels in individual monitoring wells (MW) in the shallow aquifer varied from less than 1 foot up to 7 feet from October 1991 to August 1992.

Vertical gradients calculated from seasonal water level measurements ranging from 0.023 to 0.067 were calculated between MW-21 and MW-22, screened in the upper and lower portions of the shallow aquifer, respectively. Water level measurements indicate that there is a net upward flow within this unit at this location. Vertical gradients between the perched and shallow aquifers are generally downward across the site, indicating a potential for downward movement. However, at the upgradient location (MW-20, -21, and -22) an upward gradient exists between the confined shallow aquifer and the perched zone indicating possible upward leakage at this location.

The estimated hydraulic conductivity of the shallow aquifer at Site D ranges from 5.9×10^3 to 2.8×10^4 cm/sec. Values in the range of 10^4 obtained from MW-28 are questionable and may not be an accurate representation of the aquifer conductivity. Based on an average hydraulic conductivity and groundwater gradient, the estimated average groundwater velocity in the shallow aquifer is approximately 2.03 feet per day.

6.2.4 Kitsap Formation

A dense, lacustrine, clayey silt unit of the Kitsap Formation (Qk) is below the Qva Outwash. Regionally the thickness of the Qk is approximately 200 feet. The thickness of the Kitsap Formation was not determined at Site D.



CLEAN
COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY

Figure 7
Potentiometric Contour Map
Shallow Aquifer
August 1992

CTO 0039
OPERABLE UNIT 6
SUBBASE, Bangor
ROD

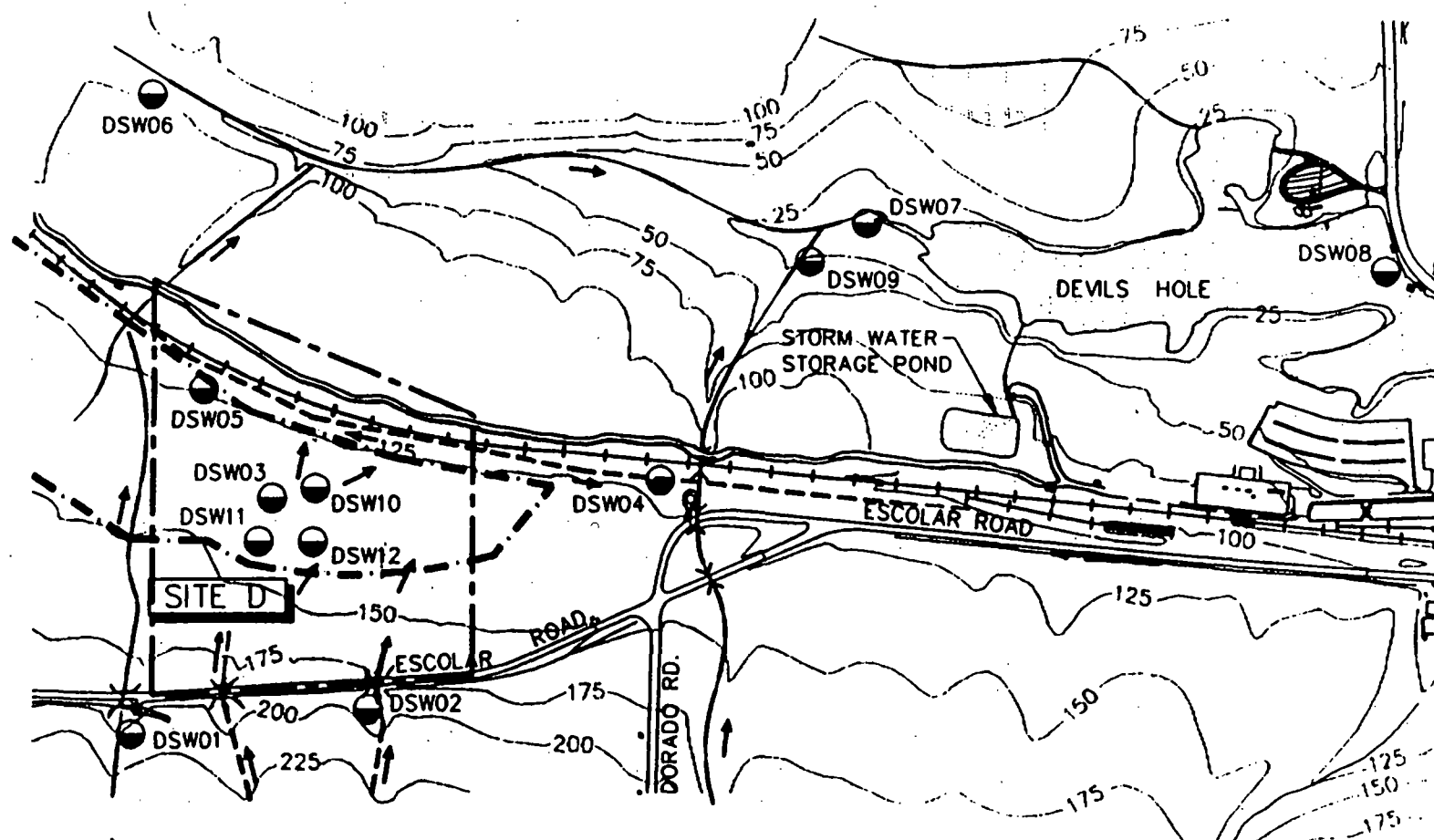
6.3 NATURE AND EXTENT OF CONTAMINATION

The remedial investigation of Site D included sampling of the site surface water, sediments, surface and subsurface soils, and groundwater. Analytical results from background sampling were used to establish naturally occurring levels of inorganic chemicals (metals) to distinguish them from increased levels resulting from activities on the site. Samples were analyzed for concentrations of all compounds on the EPA target compound list (semivolatile organics, volatile organics, and pesticides/polychlorinated biphenyls [PCBs]), for all analytes on the EPA target analyte list (metals and cyanide), ordnance compounds, and for water quality parameters.

6.3.1 Surface Water

Surface water samples were collected from Site D and vicinity during three separate sampling efforts in October and November 1991 and in February 1992. Samples were collected from three ephemeral streams in the Site D vicinity and one perennial stream on the site (Figure 8). Samples were collected on the site, upgradient of the site, and downgradient of the site during each sampling effort. Surface water quality parameters measured included temperature, specific conductance, pH, turbidity, chloride, dissolved oxygen, ammonia as nitrogen, nitrate, nitrite, total hardness, phosphorus, total dissolved solids, total organic carbon, sulfate, and alkalinity. Laboratory samples were analyzed for volatile and semivolatile organic compounds, ordnance compounds, pesticides and PCBs, and total (unfiltered) and dissolved (filtered) metals.

Findings: Table 1 lists minimum, maximum, and average concentrations of all chemicals detected in surface water at the site. Five ordnance compounds (2,4-dinitrotoluene, 2,6-dinitrotoluene, 2,4,6-trinitrotoluene, 1,3,5-trinitrobenzene, and RDX) were detected in surface water samples, although no exceedances of regulatory criteria occurred. Ordnance compounds were detected in 10 out of 32 samples collected from two surface water/sediment sampling locations (DSWs) on site (DSW-03 and DSW-10) and two locations downgradient of Site D (DSW-07 and DSW-04). The majority of ordnance detections were from samples collected near the burn trench. Regulatory criteria for metals in surface water may be based on either the total or dissolved fraction, or both, for a particular analyte. The following metals exceeded regulatory criteria in surface water samples collected from Site D: arsenic, copper, mercury, thallium, and zinc.



LEGEND:

- DIRECTION OF FLOW
- PERENNIAL STREAM
- - - EPHEMERAL STREAM
- . - . SEASONALLY WET AREA
- X CULVERT

- DSW01 ● SURFACE WATER AND SEDIMENT SAMPLING LOCATION AND NUMBER
- - - AREA OF STUDY
- + + + RAILROAD



0 300' 600'

CLEAN
COMPREHENSIVE LONG-
TERM ENVIRONMENTAL
ACTION NAVY

Figure 8
Site D
Surface Water and Sediment Sampling Locations

CTO 0039
OPERABLE UNIT 6
SUBASE, Bangor
ROD

Table 1
Chemicals Detected in Surface Water

Chemical	No. of Samples	No. of Detections	Minimum Detection (µg/L)	Maximum Detection (µg/L)	Average Detection (µg/L)	Potential ARAR Value (µg/L)
Metals—Dissolved						
Aluminum	32	29	78.7	339	172	N/A
Antimony	32	2	16.2	16.3	16.3	1,040 ^a
Arsenic	32	2	2.5	2.6	2.55	0.0842
Barium	32	28	5.3	209	68.1	N/A
Chromium	32	14	2	8.2	3.56	N/A
Copper	32	2	14.6	32.5	23.6	6.1 ^b
Iron	32	27	64.3	299	152	N/A
Lead	32	1	2.1	2.1	2.1	1.02 ^b
Manganese	32	29	2.3	69.6	13.5	N/A
Selenium	32	1	2.3	2.3	2.3	N/A
Thallium	32	1	2.4	2.4	2.4	1.56 ^a
Vanadium	32	9	2.1	4.2	2.7	N/A
Zinc	32	14	2.7	123	24.6	57
Metals—Total						
Aluminum	32	32	107	9,690	892	N/A
Arsenic	32	2	2.2	6.7	4.45	0.0842
Barium	32	29	5.3	848	104	N/A
Cadmium	32	2	1.9	4.3	3.1	N/A
Chromium	32	21	2.2	23.2	5.6	127 ^b
Cobalt	32	2	7.9	9.7	8.8	N/A
Copper	32	6	6.2	266	66.6	N/A
Iron	32	31	70.7	7,420	874	N/A
Lead	32	7	2	53.8	11.6	N/A
Manganese	32	32	3.1	865	80	N/A
Mercury	32	2	.24	.32	.28	.012
Nickel	32	2	23.8	38.3	31.1	N/A
Selenium	32	1	2.4	2.4	2.4	5
Vanadium	32	10	2.7	46	12.3	N/A
Zinc	32	13	2.6	1,000	120	N/A

Table 1 (Continued)
Chemicals Detected in Surface Water

Chemical	No. of Samples	No. of Detections	Minimum Detection (µg/L)	Maximum Detection (µg/L)	Average Detection (µg/L)	Potential ARAR Value (µg/L)
Ordinance Compounds						
1,3,5-Trinitrobenzene	32	1	0.066	0.066	0.066	N/A
2,4,6-Trinitrotoluene	25	4	0.003	2.3	0.587	N/A
2,4-Dinitrotoluene	32	2	0.057	0.12	0.089	1,360
2,6-Dinitrotoluene	32	2	0.006	0.083	0.04	N/A
RDX	28	1	3	3	3	N/A
Semivolatile Organic Compounds						
Bis(2-ethylhexyl) phthalate	32	8	0.7	51	8.3	3.56
Volatile Organic Compounds						
1,1,1-Trichloroethane	32	1	0.9	0.9	0.9	41,700
Acetone	32	6	10	20	12.2	N/A
Benzene	32	7	1	12	4	43
Chlorobenzene	32	2	1	2	1.5	5,030
Methylene chloride	32	5	5	38	28	960
Styrene	32	1	4	4	4	N/A
Toluene	32	1	2	2	2	48,500

*ARAR is based on total metal analysis

*Based on an average hardness of 55 mg/kg as CaCO₃

Notes:

The metals calcium, magnesium, potassium, and sodium are not shown due to lack of human or ecological toxicity

µg/L - micrograms per liter

ARAR - applicable or relevant and appropriate requirement

N/A - not available/not applicable

RDX - Royal Demolition Explosive (cyclonite or hexahydro-1,3,5-trinitro-1,3,5-triazine)

- Arsenic exceeded the Model Toxics Control Act (MTCA) Method B cleanup level in 2 out of 32 samples at DSW-01 (upgradient) and DSW-10 (on site)
- Copper exceeded the Washington State Water Quality Standard in 2 out of 32 samples at DSW-03 (on site)
- Mercury exceeded the Washington State Water Quality Standard in 2 out of 32 samples at DSW-03 and DSW-10 (on site)
- Thallium exceeded the MTCA Method B cleanup level in 1 out of 32 samples at DSW-05 (on site)
- Zinc exceeded the Washington State Water Quality Standard in 2 out of 32 samples at DSW-03 (on site)

The following chemicals exceeded regulatory criteria in surface water samples collected downgradient or cross-gradient from Site D: lead and bis(2-ethylhexyl) phthalate.

- Lead exceeded the Washington State Water Quality Standard in 1 out of 32 samples at DSW-09 (downgradient)
- Bis(2-ethylhexyl) phthalate exceeded the MTCA Method B cleanup level in 2 out of 32 samples at DSW-06 (cross-gradient) and DSW-08 (downgradient)

6.3.2 Freshwater Sediments

Freshwater sediment samples were collected from Site D and the vicinity during three separate sampling efforts in October and November 1991 and in February 1992.

Samples were collected from three ephemeral streams in the Site D vicinity and one perennial stream on site (Figure 8). Samples were collected on site, upgradient of the site, and downgradient of the site during each sampling effort. Samples were analyzed for volatile and semivolatile organic compounds, ordnance compounds, pesticides and PCBs, and metals.

Findings: Table 2 lists minimum, maximum, and average concentrations of all chemicals detected in freshwater sediments. The concentrations of eight metals exceeded guidance concentrations, specifically arsenic, cadmium, chromium, copper, lead, manganese, mercury, and nickel.

Sampling grids were established to collect surface soil samples from the burn/detonation areas of Site D for chemical analysis (Figure 9). Each grid was divided into 25- by 25-foot cells. Random and biased soil grab samples were collected within the grids and screened for 2,4,6-trinitrotoluene and RDX as specified in the sampling and analysis plan.

To confirm the screening results, 60 field samples and 6 duplicates were collected as splits with field screening samples and sent to an off-site laboratory for ordnance analysis.--Figure 9 depicts the locations of all laboratory confirmation samples. Additional surface soil samples were collected in the locations shown in Figure 9 and analyzed for metals to determine compliance with regulatory criteria and to evaluate potential treatment technologies.

Findings: Table 3 lists minimum, maximum, and average concentrations of all chemicals detected in surface soils. Ordnance compounds detected at concentrations that exceeded regulatory requirements were 2,4-dinitrotoluene (in 25 of 107 samples collected), 2,6-dinitrotoluene (in 4 of 107 collected), and 2,4,6-trinitrotoluene (in 11 of 107 samples collected). The concentration of the metal arsenic exceeded regulatory requirements in 3 of 74 samples collected.

Table 2
Chemicals Detected in Freshwater Sediments

Chemical	No. of Samples	No. of Detections	Minimum Detection (mg/kg)	Maximum Detection (mg/kg)	Average Detection (mg/kg)
Metals					
Aluminum	35	35	4,930	17,000	9,774
Antimony	35	14	5.9	21.1	9.13
Arsenic	35	31	0.89	6.2	2.35
Barium	35	35	16.7	198	53.6
Beryllium	35	3	0.25	0.3	0.273
Cadmium	35	9	0.46	1.5	0.939
Chromium	35	35	11	48.7	24.3
Cobalt	35	35	3.3	12.6	6.93
Copper	35	35	3.6	63	15.5
Lead	35	32	0.87	46.2	7.53
Manganese	35	35	120	430	220
Mercury	35	11	0.12	0.86	0.257
Nickel	35	35	14.1	47.8	30.7
Selenium	35	2	0.47	1.3	0.885
Silver	35	3	0.93	2.3	1.51
Vanadium	35	35	14.3	81.5	32.4
Zinc	35	35	13	157	45
Ordinance Compounds					
2,4,6-Trinitrotoluene	35	3	0.065	0.89	0.408
2,4-Dinitrotoluene	35	2	1.1	5.1	3.1
2,6-Dinitrotoluene	35	2	0.1	0.39	0.245
Semivolatile Organic Compounds					
2,4-Dinitrotoluene	35	3	0.5	4.9	2.57
Benzo(a)anthracene	35	1	0.12	0.12	0.12
Benzo(a)pyrene	35	1	0.085	0.085	0.085
Benzo(b)fluoranthene	35	1	0.19	0.19	0.19
Benzo(k)fluoranthene	35	2	0.096	0.14	0.118
Chrysene	35	2	0.09	0.14	0.115
Di-n-octylphthalate	34	1	0.12	0.12	0.12
Fluoranthene	35	2	0.11	0.25	0.18

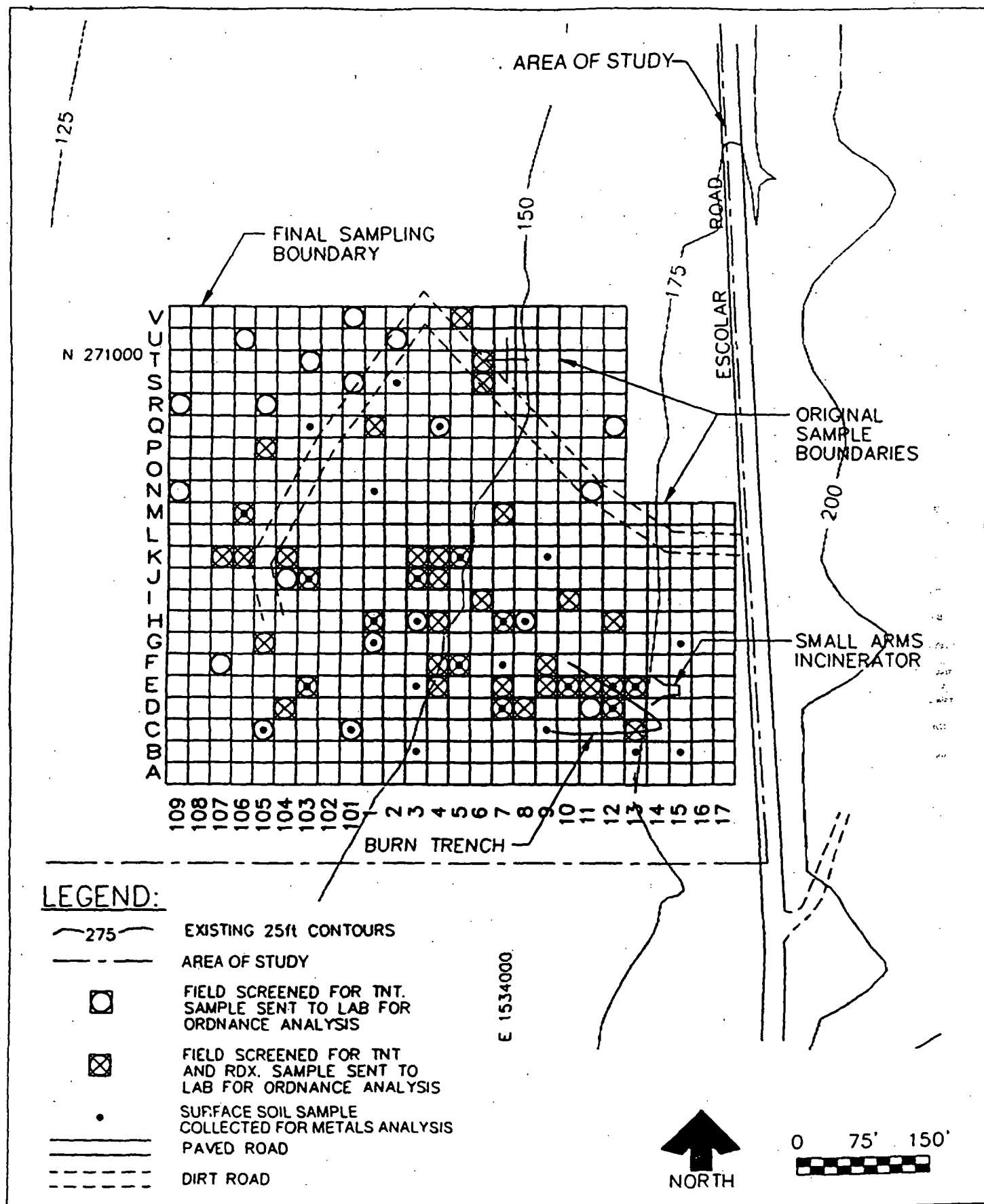
Table 2 (Continued)
Chemicals Detected in Freshwater Sediments

Chemical	No. of Samples	No. of Detections	Minimum Detection (mg/kg)	Maximum Detection (mg/kg)	Average Detection (mg/kg)
N-Nitrosodiphenylamine	35	3	0.25	0.63	0.487
Phenanthrene	35	2	0.17	0.45	0.31
Pyrene	35	2	0.18	0.44	0.31
Bis(2-ethylhexyl) phthalate	35	6	0.075	0.11	0.091
Volatile Organic Compounds					
1,1,1-Trichloroethane	35	3	0.006	0.037	0.019
2-Butanone	35	1	0.005	0.005	0.005
Acetone	35	13	0.002	0.038	0.017
Benzene	35	2	0.002	0.002	0.002
Chlorobenzene	35	2	0.001	0.003	0.002
Methylene chloride	35	14	0.003	0.097	0.029
Tetrachloroethene	35	4	0.001	0.045	0.016
Toluene	35	3	0.002	0.016	0.0073
Xylenes	35	1	0.004	0.004	0.004

Notes:

The metals calcium, iron, magnesium, potassium, and sodium are not shown due to lack of human or ecological toxicity.

mg/kg - milligrams per kilogram



CLEAN
COMPREHENSIVE LONG-
TERM ENVIRONMENTAL
ACTION NAVY

Figure 9
Site D
Surface Soil Laboratory Confirmation Samples

CTO 0039
OPERABLE UNIT 6
SUBBASE, Bangor
ROD

Table 3
Chemicals Detected in Surface Soils

Chemical	No. of Samples	No. of Detections	Minimum Detection (mg/kg)	Maximum Detection (mg/kg)	Average Detection (mg/kg)	Potential ARAR Value (mg/kg)	Background Value (mg/kg)
Metals							
Aluminum	74	74	7,760	21,000	13,835	N/A	19,546
Antimony	45	7	7.4	27.1	13.6	32	N/A
Arsenic	74	71	1.1	68.2	8.48	20	3.69
Barium	74	74	23.2	1,810	202	5,600	134
Beryllium	74	39	0.22	0.48	0.333	0.233	0.49
Cadmium	74	31	0.59	15	3.77	40	0.55
Chromium	74	74	18.3	77.7	34.1	80,000	34
Cobalt	74	64	4.7	17.5	8.08	4,800	7.75
Copper	74	74	4.9	2,230	110	2,960	16
Cyanide	18	7	0.81	3.5	1.69	1,600	N/A
Lead	74	74	0.9	1,570	51.7	N/A	31.8
Manganese	74	74	136	1,010	393	8,000	1,002
Mercury	74	8	0.12	3.2	0.594	24	0.1
Nickel	74	74	23.5	76.6	39.1	1,600	63.3
Selenium	74	5	0.49	0.95	0.804	400	N/A
Silver	74	16	0.7	27.5	3.83	240	0.97
Vanadium	74	74	26.2	115	46	560	35.7
Zinc	74	74	16.5	2,880	188	22,400	38.4
Ordnance Compounds							
1,3,5-Trinitrobenzene	107	21	0.04	3.4	0.397	4	N/A
1,3-Dinitrobenzene	107	5	0.1	2.8	0.828	8	N/A
2,4,6-Trinitrotoluene	107	53	0.025	14,000	638	33.3	N/A
2,4-Dinitrotoluene	107	49	0.045	78	5.68	1.47 ^a	N/A
2,6-Dinitrotoluene	107	38	0.018	5.6	0.643	1.47 ^a	N/A
Nitrobenzene	66	2	0.073	0.075	0.074	40	N/A
RDX	39	8	0.02	1.7	0.358	9.09	N/A
Picramic acid	41	2	0.27	0.38	0.325	N/A	N/A
Picric acid	39	4	1.5	6	3.55	N/A	N/A

Table 3 (Continued)
Chemicals Detected in Surface Soils

Chemical	No. of Samples	No. of Detections	Minimum Detection (mg/kg)	Maximum Detection (mg/kg)	Average Detection (mg/kg)	Potential ARAR Value (mg/kg)	Background Value (mg/kg)
Semivolatile Organic Compounds							
Di-n-butylphthalate	41	6	0.11	5.3	1.091	8,000	N/A
Di-n-octylphthalate	41	10	0.079	0.25	0.154	1,600	N/A
N-Nitrosodiphenylamine	41	4	0.19	7	2.85	204	N/A
Bis(2-ethylhexyl) phthalate	41	10	0.059	2.4	0.390	71.4	N/A
Volatile Organic Compounds							
1,1,1-Trichloroethane	41	1	0.027	0.027	0.027	7,200	N/A
Acetone	42	18	0.002	2	0.126	8,000	N/A
Chloroform	41	3	0.005	0.011	0.008	164	N/A
Ethylbenzene	41	1	0.003	0.003	0.003	8,000	N/A
Methylene chloride	42	20	0.002	0.15	0.014	133	N/A
Tetrachloroethene	41	14	0.001	0.02	0.0054	19.6	N/A
Trichloroethene	41	1	0.001	0.001	0.001	90.9	N/A
Xylenes	41	4	0.002	0.015	0.008	165,000	N/A

*MTCA Method B value for 2,4-dinitrotoluene and 2,6-dinitrotoluene mixture

Notes:

The metals calcium, iron, magnesium, potassium, and sodium are not shown due to lack of human or ecological toxicity.

mg/kg - milligrams per kilogram

ARAR - applicable or relevant and appropriate requirement

N/A - not available

RDX - Royal Demolition Explosive (cyclonite or hexahydro-1,3,5-trinitro-1,3,5-triazine)

6.3.4 Subsurface Soils

The soil boring program was conducted during February and March 1992. Boring locations (Figure 10) were selected in compliance with the final work plan. Thirty-seven soil borings were attempted; 36 were completed to the required depth of 15 feet. Sixteen of the 36 borings were drilled at biased locations: 1 near the incinerator foundation, 2 in the burn trench, 2 at each of the 6 previously identified mounds, and 1 at an area with surface soil staining. Twenty additional borings were completed to confirm contamination found during field screening.

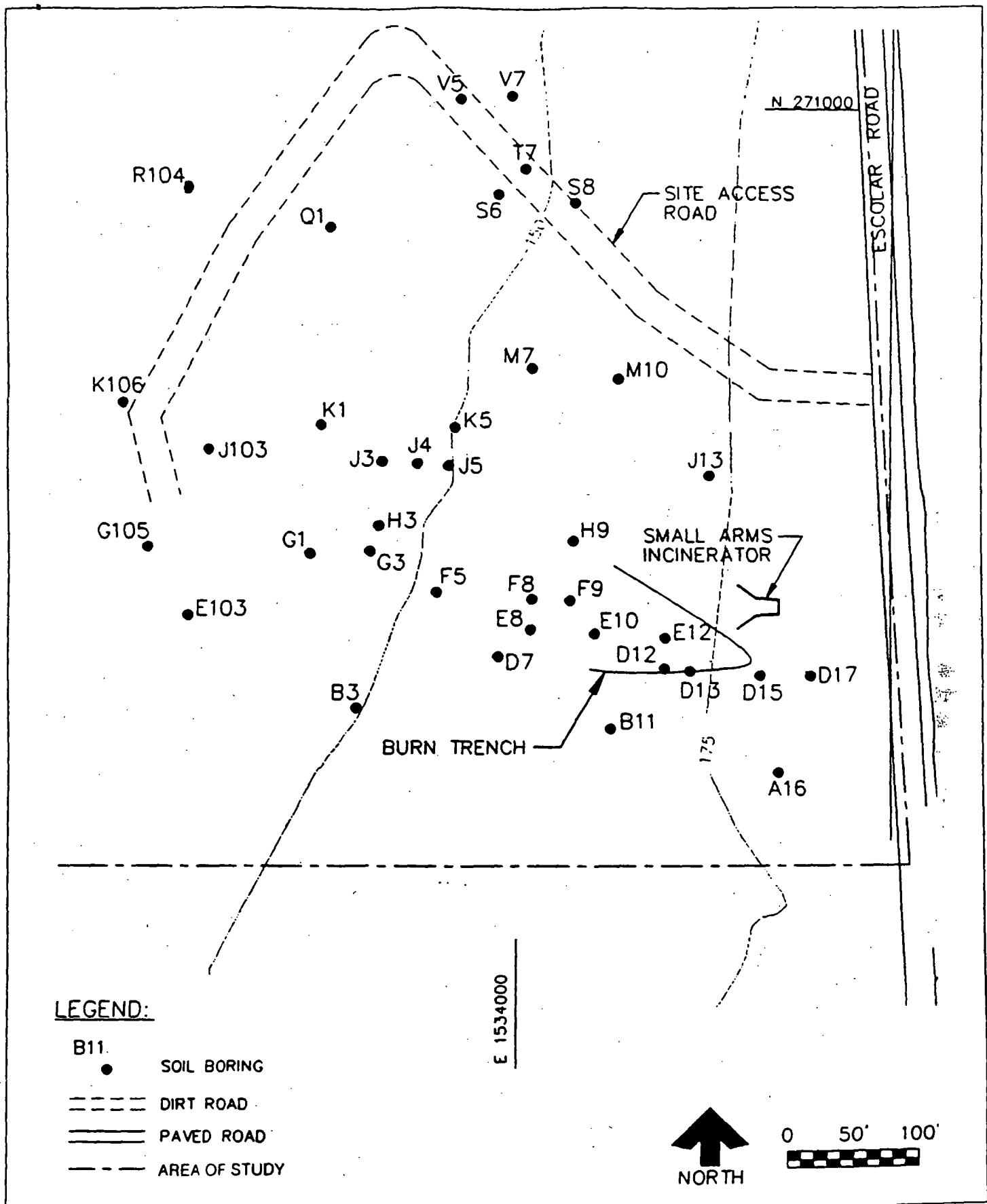
Subsurface soil samples were also collected during monitoring well installation. The final work plan specified the installation of three new well clusters (three wells per cluster) and three single wells at Site D (Figure 11). The final work plan requirements were modified based on the geologic conditions encountered, resulting in the drilling and installation of only two of the three wells in two of the three monitoring well clusters.

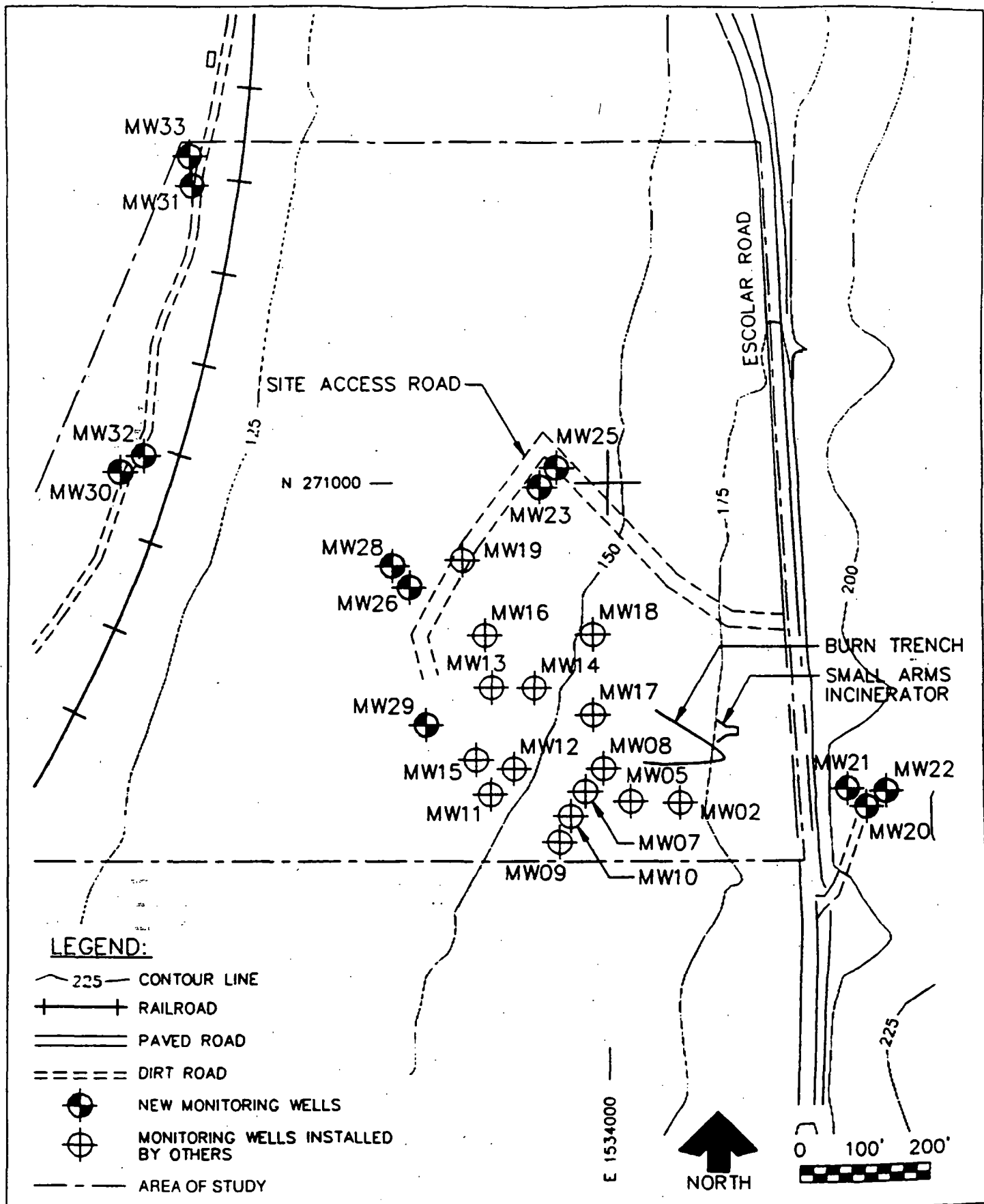
Four distinct glacial stratigraphical units were identified during this RI/FS. In order of their depth from the ground surface, shallowest to deepest, these units are the Vashon Recessional Outwash, the Vashon Till, the Vashon Advance Outwash, and the Kitsap Formation.

Subsurface soil samples were analyzed for metals, ordnance compounds, volatile and semivolatile organic compounds, and pesticides and PCBs. The findings for each glacial unit are discussed separately in the following sections.

- **Vashon Recessional Outwash**

Table 4 lists minimum, maximum, and average concentrations of chemicals detected in the Vashon Recessional Outwash. Arsenic was the only metal detected at a level that exceeded regulatory requirements in 1 sample out of 132 samples. One ordnance compound, 2,4-dinitrotoluene, exceeded regulatory requirements in 1 sample out of 132 samples.





CLEAN
COMPREHENSIVE LONG-
TERM ENVIRONMENTAL
ACTION NAVY

Figure 11
Site D
Monitoring Well Locations

CTO 0039
OPERABLE UNIT 6
SUBBASE, Bangor
ROD

Table 4
Chemicals Detected in Subsurface Soils From the Vashon Recessional Outwash

Chemical	No. of Samples	No. of Detections	Minimum Detection (mg/kg)	Maximum Detection (mg/kg)	Average Detection (mg/kg)	Potential ARAR Value (mg/kg)	Background Value
Metals							
Aluminum	132	132	4.630	21.000	10.000	N/A	14.314
Antimony	132	6	7.7	9.3	8.2	32	9.5
Arsenic	132	125	0.63	34.5	2.93	20	5.2
Barium	132	132	16	116	37	5,600	77.5
Beryllium	132	56	0.22	0.47	0.275	0.233	0.69
Cadmium	132	1	0.44	0.44	0.44	40	1.2
Chromium	132	132	14.7	61.9	28.1	80,000	42.1
Cobalt	132	132	2.9	17.7	8.05	4,800	14.9
Copper	132	132	3.8	34.9	15.8	2,960	29.6
Lead	132	127	0.79	21.4	2.55	N/A	4
Manganese	132	132	117	1,240	259	8,000	386
Mercury	132	4	0.2	0.73	0.348	24	0.11
Nickel	132	132	23.1	238	45	1,600	91.9
Selenium	132	2	0.44	0.55	0.495	400	0.74
Silver	132	8	0.47	106	22.8	240	2.4
Vanadium	132	132	15.5	125	36	560	56.4
Zinc	132	132	13.5	91.6	26.4	22,400	46
Ordinance Compounds							
1,3,5-Trinitrobenzene	132	19	0.032	0.18	0.086	4	N/A
2,4,6-Trinitrotoluene	132	36	0.021	11	0.45	33.3	N/A
2,4-Dinitrotoluene	132	2	0.03	1.8	0.915	1.47	N/A
2,6-Dinitrotoluene	132	1	0.13	0.13	0.13	1.47	N/A
Picramic acid	131	1	0.16	0.16	0.16	N/A	N/A
Picric acid	127	1	0.12	0.12	0.12	N/A	N/A
Pesticides							
Heptachlor	132	1	0.052	0.052	0.052	0.222	N/A
Semivolatile Organic Compounds							
Di-n-butylphthalate	123	11	0.009	0.98	0.193	8,000	N/A
Di-n-octylphthalate	123	40	0.01	0.76	0.218	1,600	N/A
Phenol	123	1	0.052	0.052	0.052	48,000	N/A
Pyrene	123	1	0.36	0.36	0.36	2,400	N/A
Bis(2-ethylhexyl) phthalate	123	21	0.034	0.63	0.143	71.4	N/A

Table 4 (Continued)
Chemicals Detected in Subsurface Soils From the Vashon Recessional Outwash

Chemical	No. of Samples	No. of Detections	Minimum Detection (mg/kg)	Maximum Detection (mg/kg)	Average Detection (mg/kg)	Potential ARAR Value (mg/kg)	Background Value
Volatile Organic Compounds							
1,1,1-Trichloroethane	132	5	0.001	0.002	0.0016	7,200	N/A
4-Methyl-2-pentanone	132	2	0.004	0.009	0.0065	N/A	N/A
Acetone	132	66	0.003	0.057	0.021	8,000	N/A
Chloroform	132	9	0.001	0.006	0.0036	164	N/A
Methylene chloride	132	58	0.0004	0.032	0.0074	133	N/A
Tetrachloroethene	132	14	0.0005	0.014	0.0043	19.6	N/A
Toluene	132	1	0.001	0.001	0.001	16,000	N/A
Trichloroethene	132	1	0.003	0.003	0.003	90.9	N/A
Xylenes	132	3	0.0004	0.002	0.0011	165,000	N/A

*MTC Method B value for 2,4-dinitrotoluene and 2,5-dinitrotoluene mixture

Notes:

The metals calcium, iron, magnesium, potassium, and sodium are not shown due to a lack of human or ecological toxicity.

mg/kg - milligrams per kilogram

ARAR - applicable or relevant and appropriate requirement

N/A - not available

RDX - Royal Demolition Explosive (cyclonite or hexahydro-1,3,5-trinitro-1,3,5-triazine)

- **Vashon Till**

Table 5 lists minimum, maximum, and average concentrations of chemicals detected in the Vashon Till. Beryllium was the only chemical detected at a level that exceeded regulatory requirements. This occurred in 1 sample out of 23 samples.

- **Vashon Advance Outwash**

Table 6 lists minimum, maximum, and average concentrations of chemicals detected in the Vashon Advance Outwash. Beryllium was the only chemical detected at a level that exceeded regulatory requirements. This occurred in 2 samples out of 9 samples.

- **Kitsap Formation**

Table 7 lists minimum, maximum, and average concentrations of chemicals detected in the Kitsap Formation.

No chemicals were detected at levels that exceeded regulatory requirements.

6.3.5 Groundwater

Groundwater samples were collected from 21 monitoring wells at Site D and vicinity during three separate sampling events: in the dry season in 1991, in the wet season in 1991, and in 1992. These sampling events corresponded to the seasons when groundwater is either scarce or abundant. Samples were collected from two separate water-bearing units: the perched aquifer and the shallow aquifer. During each sampling event, samples were collected at upgradient, on-site, and downgradient locations relative to the site.

Groundwater samples were analyzed for volatile and semivolatile organic compounds, ordnance compounds, pesticides and PCBs, and total (unfiltered) and dissolved (filtered) metals. The findings for groundwater samples from the perched aquifer and the shallow aquifer are discussed separately in the following sections.

- **Perched Aquifer**

Table 8 lists minimum, maximum, and average concentrations of all chemicals detected in the groundwater from the perched aquifer. Two volatile organic compounds,

Table 5
Chemicals Detected in Subsurface Soils From the Vashon Till

Chemical	No. of Samples	No. of Detections	Minimum Detection (mg/kg)	Maximum Detection (mg/kg)	Average Detection (mg/kg)	Potential ARAR Value (mg/kg)	Background Value
Metals							
Aluminum	23	23	6.050	35.600	10.993	N/A	12.258
Antimony	23	2	5.5	10.3	7.9	32	N/A
Arsenic	23	19	0.86	6.7	2.15	20	1.65
Barium	23	23	22.9	228	47.2	5.600	51.8
Beryllium	23	11	0.22	0.83	0.325	0.233	0.68
Chromium	23	23	14.6	86.4	29.9	80.000	26.6
Cobalt	23	23	5.4	32.4	9.21	4.800	10.6
Copper	23	23	8.6	71.9	19.5	2.960	24.4
Lead	23	22	1.2	12	2.48	N/A	1.97
Manganese	23	23	158	1,020	282	8.000	311
Nickel	23	23	24.7	117	42.4	1.600	76.9
Vanadium	23	23	20.9	101	37.3	560	36.9
Zinc	23	23	17.2	123	31.5	22,400	31.5
Ordinance Compounds							
1,3,5-Trinitrobenzene	23	3	0.082	0.14	0.121	4	N/A
2,4,6-Trinitrotoluene	23	5	0.021	0.053	0.037	33.3	N/A
Pesticides							
Methoxychlor	23	1	0.17	0.17	0.17	400	N/A
Semivolatile Organic Compounds							
Di-n-octylphthalate	22	7	0.08	0.25	0.128	1.600	N/A
Bis(2-ethylhexyl) phthalate	22	4	0.034	0.13	0.101	71.4	N/A
Volatile Organic Compounds							
Acetone	23	8	0.007	0.041	0.018	8.000	N/A
Chloroform	23	1	0.006	0.006	0.006	164	N/A
Methylene chloride	23	8	0.002	0.006	0.004	133	N/A
Tetrachloroethene	23	1	0.003	0.003	0.003	19.6	N/A

Notes:

The metals calcium, iron, magnesium, potassium, and sodium are not shown due to a lack of human or ecological toxicity.

mg/kg - milligrams per kilogram

ARAR - applicable or relevant and appropriate requirement

N/A - not available

Table 6
Chemicals Detected in Subsurface Soils From the Vashon Advance Outwash

Chemical	No. of Samples	No. of Detections	Minimum Detection (mg/kg)	Maximum Detection (mg/kg)	Average Detection (mg/kg)	Potential ARAR Value (mg/kg)	Background Value
Metals							
Aluminum	9	9	7.000	32.000	15.304	N/A	14.094
Antimony	9	2	9.3	10.5	9.9	32	N/A
Arsenic	9	5	0.97	5.5	2.97	20	5.1
Barium	9	9	28.9	185	79.5	5,600	76.6
Beryllium	9	6	0.24	0.72	0.46	0.233	0.58
Chromium	9	9	18.7	70.8	37.3	80,000	41.8
Cobalt	9	9	6.3	23.7	12.6	4,800	14.7
Copper	9	9	8.7	54.2	24.8	2,960	29.4
Lead	9	7	1.5	14.2	5.8	N/A	3.94
Manganese	9	9	204	835	398	8,000	385.6
Mercury	9	2	0.12	0.39	0.255	24	0.06
Nickel	9	9	32.4	84.2	51.7	1,600	91.8
Selenium	9	1	0.69	0.69	0.69	400	N/A
Vanadium	9	9	22	88.6	46.9	560	55.7
Zinc	9	9	23.4	102	51.2	22,400	45.9
Semivolatile Organic Compounds							
1,2,4-Trichlorobenzene	9	1	0.27	0.27	0.27	800	N/A
1,4-Dichlorobenzene	9	1	0.26	0.26	0.26	41.7	N/A
4-Chloro-3-methylphenol	9	1	0.6	0.6	0.6	N/A	N/A
Acenaphthene	9	1	0.39	0.39	0.39	4,800	N/A
Di-n-octylphthalate	9	1	0.47	0.47	0.47	1,600	N/A
Phenol	9	1	0.57	0.57	0.57	48,000	N/A
Pyrene	9	1	0.43	0.43	0.43	2,400	N/A
Bis(2-ethylhexyl) phthalate	9	1	0.042	0.042	0.042	71.4	N/A
Volatile Organic Compounds							
1,1,1-Trichloroethane	9	1	0.004	0.004	0.004	7,200	N/A
1,2-Dichloroethene	9	1	0.0007	0.0007	0.0007	N/A	N/A
Acetone	9	5	0.019	0.044	0.029	8,000	N/A
Chloroform	9	1	0.006	0.006	0.006	164	N/A
Ethylbenzene	9	1	0.001	0.001	0.001	8,000	N/A
Methylene chloride	9	4	0.006	0.022	0.0133	133	N/A
Tetrachloroethene	9	5	0.001	0.037	0.0106	19.6	N/A
Trichloroethene	9	1	0.007	0.007	0.007	90.9	N/A
Xylenes	9	2	0.001	0.001	0.001	165,000	N/A

Notes:

The metals calcium, iron, magnesium, potassium, and sodium are not shown due to a lack of human or ecological toxicity.

mg/kg - milligrams per kilogram

ARAR - applicable or relevant and appropriate requirement

N/A - not available

Table 7
Chemicals Detected in Subsurface Soils From the Kitsap Formation

Chemical	No. of Samples	No. of Detections	Minimum Detection (mg/kg)	Maximum Detection (mg/kg)	Average Detection (mg/kg)	Potential ARAR Value (mg/kg)	Background Value
Metals							
Aluminum	4	4	14,500	35,200	21,425	N/A	32,400
Antimony	4	2	8.2	12.6	10.4	32	N/A
Arsenic	4	4	3.7	6.8	4.83	20	7.24
Barium	4	4	83	216	123	5,600	178.8
Beryllium	4	4	0.34	0.8	0.528	0.233	1.52
Chromium	4	4	40.4	83.3	54.5	80,000	72.6
Cobalt	4	4	13.2	28.4	18.5	4,800	28.2
Copper	4	4	24.8	65.9	38.5	2,960	65.2
Lead	4	4	3.9	10.4	6.23	N/A	9.01
Manganese	4	4	402	958	594	8,000	837
Nickel	4	4	56.7	103	70	1,600	96.9
Selenium	4	1	0.59	0.59	0.59	400	N/A
Vanadium	4	4	49.7	98.4	68.8	560	108.5
Zinc	4	4	52.4	119	74.6	22,400	114.9
Semi-volatile Organic Compounds							
Benzo(a)pyrene	4	1	0.067	0.067	0.067	0.137	N/A
Volatile Organic Compounds							
Acetone	4	3	0.16	0.19	0.177	8,000	N/A
Chloroform	4	1	0.007	0.007	0.007	164	N/A
Methylene chloride	4	1	0.001	0.001	0.001	133	N/A
Xylenes	4	1	0.005	0.005	0.005	165,000	N/A

Notes:

The metals calcium, iron, magnesium, potassium, and sodium are not shown due to a lack of human or ecological toxicity.

mg/kg - milligrams per kilogram

ARAR - applicable or relevant and appropriate requirement

N/A - not available

Table 8
Chemicals Detected in Groundwater From the Perched Aquifer

Chemical	No. of Samples	No. of Detections	Minimum Detection (µg/L)	Maximum Detection (µg/L)	Average Detection (µg/L)	Potential ARAR Value (µg/L)	Background Value
Metals*							
Aluminum	25	16	71.1	230	134	N/A	148
Arsenic	25	2	7.2	33.9	20.6	0.05	3
Barium	25	15	4.3	161	69.8	1,000	21
Chromium	25	6	2.5	7.4	4.93	50	N/A
Cobalt	25	1	6.4	6.4	6.4	960	N/A
Copper	25	12	5.3	29.9	12.2	592	N/A
Iron	25	18	9.1	531	99.7	N/A	162
Lead	25	12	1.1	3.8	1.98	15	N/A
Manganese	25	24	1.4	3,370	312	1,600	176
Mercury	25	5	0.24	0.29	0.264	2	N/A
Nickel	25	8	8.1	30.9	13.4	100	N/A
Selenium	25	3	2.2	3.3	2.73	10	N/A
Vanadium	25	4	2	4	2.85	112	N/A
Zinc	25	18	4.4	58.6	14.2	4,800	15
Ordinance Compounds							
1,3,5-Trinitrobenzene	22	4	0.24	24	14.3	0.8	N/A
2,4,6-Trinitrotoluene	16	2	1.6	33	17.3	2.92	N/A
2,4-Dinitrotoluene	25	6	0.097	0.19	0.139	0.129*	N/A
2,6-Dinitrotoluene	24	6	0.015	0.45	0.281	0.129*	N/A
RDX	23	4	0.061	4	1.46	0.795	N/A
Semivolatile Organic Compounds							
Benzoic acid	25	1	1	1	1	64,000	N/A
Butylbenzylphthalate	25	1	0.6	0.6	0.6	100	N/A
Di-n-butylphthalate	25	2	1	4	2.5	1,600	N/A
Di-n-octylphthalate	25	8	3	13	6.38	320	N/A
Diethylphthalate	25	1	0.9	0.9	0.9	12,800	N/A
Naphthalene	25	2	1	4	2.5	32	N/A
Pentachlorophenol	25	1	1	1	1	0.729	N/A
Phenol	25	1	2	2	2	9,000	N/A
Pyrene	25	1	1	1	1	480	N/A
Bis(2-ethylhexyl) phthalate	25	6	1	7	3.5	6	N/A
Volatile Organic Compounds							
Acetone	25	4	11	26	16	800	N/A

Table 8 (Continued)
Chemicals Detected in Groundwater From the Perched Aquifer

Chemical	No. of Samples	No. of Detections	Minimum Detection (µg/L)	Maximum Detection (µg/L)	Average Detection (µg/L)	Potential ARAR Value (µg/L)	Background Value
Chlorobenzene	25	1	3	3	3	100	N/A
Dibromochloromethane	25	1	2	2	2	100	N/A
Methylene chloride	25	3	3	26	11	5.83	N/A
Tetrachloroethene	25	1	2	2	2	0.858	N/A
Toluene	25	2	3	5	4	1,000	N/A
Xylenes	25	1	6	6	6	10,000	N/A

*Dissolved metals

*MTCA Method B value for 2,4-dinitrotoluene and 2,6-dinitrotoluene mixture

Notes:

The metals calcium, magnesium, potassium, and sodium are not shown due to not shown due to lack of human or ecological toxicity.

µg/L - micrograms per liter

ARAR - applicable or relevant and appropriate requirement

N/A - not available

RDX - Royal Demolition Explosive (cyclonite or hexahydro-1,3,5-trinitro-1,3,5-triazine)

methylene chloride and tetrachloroethene, were detected in 1 sample out of 25 samples, each at concentrations exceeding regulatory criteria. Methylene chloride is a common laboratory contaminant. Two semivolatile organic compounds, pentachlorophenol and bis(2-ethylhexyl) phthalate, were each detected at concentrations greater than regulatory criteria in 1 out of 25 samples. Five ordnance compounds were detected at levels above regulatory criteria. The concentration of 2,4-dinitrotoluene exceeded regulatory requirements in 4 of 25 samples, 2,6-dinitrotoluene in 5 of 24 samples, RDX in 2 of 23 samples, 1,3,5-trinitrobenzene in 3 of 22 samples, and 2,4,6-trinitrotoluene in 1 of 16 samples. Concentrations of the metals arsenic and manganese exceeded regulatory requirements in 2 of 25 samples.

- **Shallow Aquifer**

Table 9 lists minimum, maximum, and average concentrations of all chemicals detected in groundwater from the shallow aquifer. The volatile organic compounds benzene and tetrachloroethene were detected at concentrations greater than regulatory requirements; benzene in 1 sample out of 26 (at DMW-22) and tetrachloroethene in 2 samples out of 26 (at DMW-21 and DMW-32). Concentrations of methylene chloride exceeded regulatory requirements in 5 out of 26 samples; however, methylene chloride is a common laboratory contaminant. The pesticide heptachlor was detected in one sample at a concentration greater than regulatory requirements. The semivolatile organic compound bis(2-ethylhexyl) phthalate was detected at a level greater than regulatory requirements in 3 out of 26 samples and was detected in a laboratory blank. Concentrations of two metals, arsenic and beryllium, exceeded regulatory requirements in 9 out of 26 samples and 6 out of 26 samples, respectively.

6.4 PHYSICAL AND CHEMICAL BEHAVIOR OF ORDNANCE COMPOUNDS

The two most important transformation processes controlling the fate and distribution of ordnance compounds in the environment are, in general, microbiological and photochemical transformation. Oxidation and reduction, and hydrolysis are not considered significant mechanisms for the transformation of 2,4,6-trinitrotoluene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, 1,3,5-trinitrobenzene, and 1,3-dinitrobenzene.

The compounds 2,4,6-trinitrotoluene and 1,3,5-trinitrobenzene are microbially transformed, but are not completely mineralized to inorganic products and are known to persist in soil and sediment for years. The compounds 2,4-dinitrotoluene,

Table 9
Chemicals Detected in Groundwater From the Shallow Aquifer

Chemical	No. of Samples	No. of Detections	Minimum Detection (µg/L)	Maximum Detection (µg/L)	Average Detection (µg/L)	Potential ARAR Value (µg/L)	Background Value
Metals*							
Arsenic	26	9	2.6	22.4	8.51	0.05	3
Barium	26	23	7.3	133	29.1	1,000	21
Beryllium	26	6	1	1.3	1.15	0.0203	1
Cadmium	26	3	2	6.1	3.6	8	N/A
Chromium	26	8	2.6	4.1	3.74	50	N/A
Cobalt	26	1	4	4	4	960	N/A
Copper	26	12	6	16.1	9.92	592	N/A
Lead	26	14	1.3	5	3.09	15	N/A
Manganese	26	25	17.4	276	114	1,600	176
Mercury	26	4	0.2	0.32	0.27	2	N/A
Nickel	26	1	9.2	9.2	9.2	100	N/A
Selenium	26	1	3	3	3	10	N/A
Silver	26	1	2	2	2	50	N/A
Vanadium	26	1	7.8	7.8	7.8	112	N/A
Zinc	24	18	2.2	426	43.4	4,800	N/A
Pesticides							
4,4-DDT	26	1	0.0072	0.0072	0.0072	0.257	N/A
Heptachlor	26	1	0.064	0.064	0.064	0.0194	0
Semivolatile Organic Compounds							
Benzoic acid	26	1	1	1	1	64,000	N/A
Butylbenzylphthalate	26	1	2	2	2	100	N/A
Di-n-butylphthalate	26	1	2	2	2	1,600	N/A
Di-n-octylphthalate	26	1	0.03	0.03	0.03	320	N/A
Naphthalene	26	1	2	2	2	32	N/A
Bis(2-ethylhexyl) phthalate	26	7	1	130	27.1	6	N/A
Volatile Organic Compounds							
1,1,1-Trichloroethane	26	1	6	6	6	200	N/A
Acetone	26	2	15	55	35	800	N/A
Benzene	26	2	1	7	4	1.51	N/A
Chloroform	26	1	2	2	2	100	N/A
Methylene chloride	26	6	5	17	11.3	5.83	N/A
Tetrachloroethene	26	2	1	2	1.5	0.858	N/A

*Dissolved metals

Notes:

The metals aluminum, calcium, iron, magnesium, potassium, and sodium are not shown due to lack of human toxicity.

µg/L - micrograms per liter

ARAR - applicable or relevant and appropriate requirement

N/A - not available

4,4-DDT - 4,4-dichlorodiphenyltrichloroethane

2,6-dinitrotoluene, and 1,3-dinitrobenzene, unlike 2,4,6-trinitrotoluene, have been shown to be biodegradable to inorganic products such as nitrate and carbon dioxide. The transformation processes of 2,4,6-trinitrotoluene, 2,4-dinitrotoluene, and 2,6-dinitrotoluene involve the successive reduction of nitro groups to amino groups to form amino derivatives of 2,4-dinitrotoluene and 2,6-dinitrotoluene. The metabolic transformation products of 2,4,6-trinitrotoluene are adsorbed strongly to organic materials and have significantly lower toxicity than 2,4,6-trinitrotoluene, 2,4-dinitrotoluene, and 2,6-dinitrotoluene. High organic carbon concentrations, aerobic conditions, and the presence of readily biodegradable co-substrate have been found to enhance the biotransformation of 2,4,6-trinitrotoluene. High concentrations of 2,4,6-trinitrotoluene can inhibit the development of an acclimated microbiota. Biotransformation is expected to be an important process in sediment and surface soils.

Photochemical transformation of 2,4,6-trinitrotoluene occurs at a higher rate than biotransformation. Ordnance compounds typically undergo reduction of nitryl groups, followed by oxidation of methyl groups. The primary photochemical transformation by-product of 2,4,6-trinitrotoluene in natural surface water appears to be 1,3,5-trinitrobenzene, which is relatively stable to further photodegradation. The phototransformation rate for 2,4,6-trinitrotoluene is inversely proportional to the water pH. Phototransformation of ordnance compounds is expected to be an important process in surface waters.

Although the quantity of 2,4,6-trinitrotoluene released to the environment at Site D is unknown, the compound appears to be transforming, as indicated by the number of detections and the concentrations of the 2,4,6-trinitrotoluene transformation products 1,3,5-trinitrobenzene and 1,3-dinitrobenzene. As indicated by their high octanol:water partition coefficients, the compounds 2,4,6-trinitrotoluene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, 1,3,5-trinitrobenzene, and 1,3-dinitrobenzene are all strongly adsorbed to humus and clays. Ordnance concentrations in the area downgradient from the burn trench are possibly the result of surface water runoff and erosion of soil and organic particles containing ordnance compounds. Erosion is probably the primary transport pathway causing the spread of ordnance compounds. This explanation is supported by surface water sampling that showed that all detections of ordnance compounds in surface water occurred during storm event sampling. The wider area of the surface detections for both field screening and laboratory results corresponds to a decrease in slope west of the burn trench. Over time, erosion is expected to transport soil particles containing ordnance compounds further downgradient at Site D, and ultimately into the perennial streams that drain into Devil's Hole.

Most of the ordnance compounds occur in the top 3 feet of the soil column. This finding is consistent with the fact that ordnance compounds are strongly adsorbed by soil and organic material. The compound 1,3,5-trinitrobenzene is considerably more mobile than 2,4,6-trinitrotoluene and would be expected to migrate both vertically and horizontally away from the original source.

7.0 SUMMARY OF SITE RISKS

7.1 HUMAN HEALTH RISK ASSESSMENT AND CHARACTERIZATION

The baseline risk assessment in Section 6.0 of the RI/FS (URS 1993) estimated the probabilities of adverse health effects from current and future hypothetical exposures to chemicals of concern in the absence of remediation. The risk assessment is a multistep process consisting of data evaluation, chemical toxicity assessments, and exposure assessments. By combining the information gathered during each of these three steps, noncancer and cancer risks can be quantified in a final step termed risk characterization.

All chemicals detected at Site D were screened in accordance with EPA guidelines to select chemicals of potential concern (COPCs) for evaluation in the risk assessment. Inorganic chemicals whose maximum detected concentrations were less than the calculated background concentration for OU 6 were screened from the risk assessment. A detailed exposure assessment followed, which consisted of evaluating the specific exposure setting and exposure pathways. Default exposure assumptions are defined in current EPA risk assessment guidance. (Site-specific exposure assumptions for Site D are explained in Section 6.0 of the RI/FS.) Toxicity information obtained from EPA's Integrated Risk Information System (IRIS) database was then applied to each COPC.

Noncancer risks were quantified by comparing the estimated intake dose resulting from site exposure to a reference dose (RfD), an EPA estimate of the acceptable daily intake of a chemical. Hazard indexes (HIs) greater than 1.0 were considered a concern.

Cancer risks were expressed as an excess probability that an individual will develop cancer if exposed to a chemical over a lifetime. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) states that acceptable risks lie between 10^{-4} and 10^{-6} . For example, a risk expressed as 1.0×10^{-6} means that 1 person out of

1,000,000 exposed people may develop cancer over a lifetime of exposure to the specified chemicals at the site.

Three exposure scenarios were evaluated: the current worker, the future worker, and the future resident. These scenarios were evaluated on the basis of cancer and noncancer risks for all significant pathways of exposure.

The COPCs for Site D are presented in Table 10. The total HI and cancer risk for each pathway for the future residential scenario are shown in Table 11. The primary chemicals of concern contributing to the total risk at Site D are 2,4,6-trinitrotoluene and 2,4-dinitrotoluene in surface soils, and arsenic in groundwater in the shallow aquifer. These risks represent all chemicals detected at the site and include risks for inorganic chemicals that were not eliminated in the background screening step. Although it was not possible to screen out all inorganic chemicals in the background screening step, the on-site concentrations of inorganics were generally consistent with the concentrations measured in the area background. HIs and cancer risks associated with naturally occurring area-wide levels of inorganics in soil and groundwater are shown in Table 12.

The excess noncancer HI (summed across all chemicals and exposure pathways) and excess cancer risk for each scenario for Site D are shown in Table 13. These risk estimates, called incremental risks, do not include risks from metals in the soil and groundwater, which were attributed to naturally occurring conditions and are not related to previous activities at the site. The total groundwater risks for Site D were predominantly due to naturally occurring levels of background inorganics. Groundwater risks in the 10^{-6} range were associated with bis(2-ethylhexyl) phthalate, a common laboratory contaminant, and heptachlor, which was detected in 1 sample out of 26 samples.

The incremental HI for noncancer risk at Site D for the hypothetical future resident (the most conservative) is 5.0, which exceeds the threshold value of 1.0. This incremental noncancer risk is due almost entirely to 2,4,6-trinitrotoluene in surface soil. The incremental cancer risk for the future resident is approximately 5.0×10^{-5} . Approximately 70 percent of the incremental cancer risk is due to 2,4,6-trinitrotoluene and 2,4-dinitrotoluene in soil. The remainder of the incremental cancer risk is attributable to infrequent detections of heptachlor and bis(2-ethylhexyl) phthalate in groundwater and PAH compounds in sediments.

Table 10
Reasonable Maximum Exposure Concentrations
for Chemicals of Potential Concern—Human Health Evaluation

Chemical	Surface Water (mg/L)	Soil/Sediment 0 to 3 feet (mg/kg)	Soil/Sediment 0 to 12 feet (mg/kg)	Shallow Unfiltered Groundwater (mg/L)
Ordinance Compounds				
2,4-Dinitrotoluene	0.00006	3.7	2.0	ND
2,6-Dinitrotoluene	0.00045	0.35	0.19	ND
Nitrobenzene	ND	0.075	0.075	ND
Picramic acid	ND	0.064	0.051	ND
Picric acid	ND	0.29	0.17	ND
RDX	0.004	0.43	0.24	ND
1,3,5-Trinitrobenzene	0.0043	0.21	0.14	ND
2,4,6-Trinitrotoluene	0.0045	530	280	ND
Volatile Organic Compounds				
Acetone	0.0084	0.11	0.047	0.009
Benzene	0.0026	0.002	0.002	ND
2-Butanone	ND	0.005	0.005	ND
Chlorobenzene	0.0025	0.003	0.003	ND
Chloroform	ND	0.0054	0.0038	ND
Dibromochloromethane	0.002	ND	ND	ND
Ethylbenzene	ND	0.003	0.003	ND
4-Methyl-2-pentanone	ND	ND	0.0074	ND
Methylene chloride	0.0048	0.015	0.0086	0.0088
Styrene	0.0026	ND	ND	ND
Tetrachloroethene	0.002	0.0059	0.004	ND
Toluene	0.0027	0.0054	0.0037	ND
1,1,1-Trichloroethane	0.0009	0.0068	0.0042	ND
Trichloroethene	ND	0.001	0.003	ND
Xylenes	0.0028	0.0055	0.0037	ND
Semivolatile Organic Compounds/Pesticides				
Benzo(a)anthracene	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	0.19	0.19	ND
Benzo(k)fluoranthene	ND	0.096	0.096	ND
Benzo(a)pyrene	ND	ND	ND	ND

Table 10 (Continued)
Reasonable Maximum Exposure Concentrations
for Chemicals of Potential Concern—Human Health Evaluation

Chemical	Surface Water (mg/L)	Soil/Sediment 0 to 3 feet (mg/kg)	Soil/Sediment 0 to 12 feet (mg/kg)	Shallow Unfiltered Groundwater (mg/L)
Benzoic acid	0.001	ND	ND	ND
Butylbenzylphthalate	0.0006	ND	ND	0.002
Chrysene	ND	0.09	0.09	ND
4,4'-DDT	ND	ND	ND	ND
Di-n-butylphthalate	0.001	0.68	0.47	0.002
Diethylphthalate	0.0009	ND	ND	ND
1,3-Dinitrobenzene	ND	0.19	0.14	ND
Di-n-octylphthalate	0.006	0.25	0.42	0.00003
Bis(2-ethylhexyl) phthalate	0.0063	0.63	0.44	0.041
Fluoranthene	ND	ND	ND	ND
Heptachlor	ND	ND	0.01	0.000036
Naphthalene	0.004	ND	ND	ND
N-Nitrosodiphenylamine	ND	0.87	0.55	ND
Pentachlorophenol	0.001	ND	ND	ND
Phenanthrene	ND	ND	ND	ND
Phenol	0.002	ND	ND	ND
Pyrene	0.001	ND	0.36	ND
Metals				
Antimony	ND	6.5	4.5	ND
Arsenic	0.0047	8.9	5.8	0.0093
Barium	0.19	230	130	0.14
Beryllium	0.0011	0.24	0.21	< Background
Cadmium	0.0012	2.2	1.1	ND
Chromium	0.03	33	31	< Background
Cobalt	0.011	7.5	7.7	< Background
Copper	0.051	150	76	0.049
Cyanide	ND	1.2	1.2	ND
Lead	0.013	78	36	< Background
Manganese	0.46	400	330	0.5
Mercury	0.00019	0.19	0.12	0.00018
Nickel	0.063	38	44	0.1

Table 10 (Continued)
Reasonable Maximum Exposure Concentrations
for Chemicals of Potential Concern—Human Health Evaluation

Chemical	Surface Water (mg/L)	Soil/Sediment 0 to 3 feet (mg/kg)	Soil/Sediment 0 to 12 feet (mg/kg)	Shallow Unfiltered Groundwater (mg/L)
Selenium	0.0058	0.43	0.37	0.01
Silver	0.0011	2.0	1.3	< Background
Thallium	ND	ND	ND	0.006
Vanadium	0.036	46	41	< Background
Zinc	0.13	230	120	< Background

Notes:

mg/L - milligrams per liter

mg/kg - milligrams per kilogram

ND - not detected

< Background - concentration less than background concentration

Table 11
Total Hazard Index and Cancer Risk for Site D for Future Resident

Exposure Pathway	Hazard Index	Cancer Risk
Incidental soil ingestion	2.3	1 in 27,000 (3.7×10^{-5})
Dermal contact with soil	2.7	1 in 50,000 (2.0×10^{-5})
Ingestion of groundwater	6.0	1 in 5,000 (2.0×10^{-4})
Inhalation of groundwater	<0.1	1 in 5,900,000 (1.7×10^{-7})
Dermal contact with surface water	<0.1	1 in 2,000,000 (5.1×10^{-7})
Total risk	11.0	1 in 4,000 (2.6×10^{-4})

Table 12
Total Hazard Index and Cancer Risk for Naturally Occurring Inorganic Compounds Detected in Area Background Samples

Scenario	Hazard Index	Cancer Risk
Current worker	<0.1	1 in 3,800,000 (2.6×10^{-7})
Future worker	3.0	1 in 10,000 (9.7×10^{-5})
Future resident	8.6	1 in 5,000 (2.1×10^{-4})

Table 13
Total Incremental Hazard Index and Cancer Risk for Site D

Scenario	Hazard Index		Cancer Risk	
	Total	Primary Contributors ^a	Total	Primary Contributors ^b
Current worker	0.5	2,4,6-trinitrotoluene 0.4	3.6×10^{-6}	2,4,6-trinitrotoluene 2.4×10^{-6}
Future worker	1.3	2,4,6-trinitrotoluene 1.2	1.1×10^{-5}	2,4,6-trinitrotoluene 6.2×10^{-6} 2,4-dinitrotoluene 1.0×10^{-6} bis(2-ethylhexyl)phthalate 2.0×10^{-6}
Future resident	5.0	2,4,6-trinitrotoluene 4.7	5.0×10^{-5}	2,4,6-trinitrotoluene 3.0×10^{-5} 2,4-dinitrotoluene 4.8×10^{-6} benzo(b)fluoranthene 2.2×10^{-6} benzo(k)fluoranthene 1.1×10^{-6} beryllium 1.4×10^{-6} bis(2-ethylhexyl)phthalate 6.7×10^{-6} chrysene 1.0×10^{-6} heptachlor 2.1×10^{-6}

^aIncludes those chemicals contributing a Hazard Index of 0.1 or greater

^bIncludes those chemicals contributing a cancer risk of 1.0×10^{-6} or greater

Note: The incremental risks presented in this table represent only site-related chemicals. The risks posed by naturally occurring inorganic chemicals are not included.

7.2 ECOLOGICAL RISK ASSESSMENT

The purpose of the ecological risk assessment was to determine potential toxicological threats that chemicals released into the environment at Site D may pose to sensitive ecological receptors. For purposes of the ecological risk assessment, Site D was separated into two areas: the burn trench and the main area. This ecological assessment encompassed both areas.

The approach to the ecological risk assessment followed both federal (U.S. EPA 1986, 1989a, 1989b, 1990, 1992a) and Washington State (Ecology 1991) guidance. Exposure modeling was used to evaluate potential risks. Exposure models use results of chemical analysis, chemical biotransfer factors, and exposure factors to provide conservative dose estimates for receptors. Estimated doses are compared with conservative toxicity reference values (TRVs) to evaluate potential risks. There is considerable uncertainty associated with exposure modeling, because the biotransfer and exposure factors are not unique to the site.

The ecological assessment evaluated potential risks from two matrices: surface soil and surface water. Most of Site D is characterized as seasonal wetlands with saturated or nearly saturated soil during periods of high precipitation. Because of the minimal aquatic habitat associated with this site, aquatic populations are limited to amphibians. This ecological assessment focused exposure modeling on terrestrial species.

Table 14 lists the ecological COPCs for soils and surface water and their associated RME concentrations. Because the ecological risk assessment uses exposure assumptions different from the human health risk assessment, the ecological RME concentrations are somewhat different from the human health RME concentrations. These chemicals were used for the exposure modeling for the Townsend's vole, the black-tailed deer, the long-tailed weasel, and the northern pygmy owl.

Table 15 shows the results of the exposure modeling for hazard quotients (HQs) greater than 1.0. The Townsend's vole had HQs greater than 1.0 for aluminum, cadmium, copper, lead, zinc, 1,3,5-trinitrobenzene, 2,4,6-trinitrotoluene, and 2,4-dinitrotoluene. The TRVs for aluminum, copper, lead, and zinc were based on the most toxic form of the metals known. Because the chemical forms of metals were not determined, it was difficult to ascertain the potential risks these metals pose. With the possible exception of cadmium, the metals are not likely to be on site in their most toxic form; thus, they do not pose significant risks.

Table 14
Chemicals of Potential Concern—Ecological Evaluation

Chemical	Soil RME Concentration (mg/kg)	Surface Water RME Concentration (mg/L)
Metals		
Aluminum	15,900	10.1
Antimony	6.96	N/A
Arsenic	9.35	N/A
Barium	536	0.94
Cadmium	6.22	0.0012
Chromium	34.5	0.03
Cobalt	8.91	0.011
Copper	301	0.051
Mercury	0.21	0.00019
Nickel	45.1	N/A
Selenium	N/A	0.0058
Silver	N/A	0.0011
Vanadium	53.3	0.036
Zinc	447	0.132
Ordinance Compounds		
2,4-Dinitrotoluene	8.44	N/A
2,6-Dinitrotoluene	1.16	N/A
1,3,5-Trinitrobenzene	0.742	N/A
2,4,6-Trinitrotoluene	2,830	N/A
Volatile Organic Compounds		
Tetrachloroethene	0.0048	N/A

Notes:

RME - reasonable maximum exposure

mg/kg - milligrams per kilogram

N/A - not considered a chemical of potential concern in this medium

Table 15
Hazard Quotients Greater Than 1.0 for Ecological Receptors

Chemical	Townsend's Vole	Black-Tailed Deer	Long-Tailed Weasel	Northern Pygmy Owl
Metals				
Aluminum	1.46		2.27	2.24
Cadmium	5.06			
Copper	3.49			
Lead	1.55		3.03	
Vanadium			1.39	
Zinc	1.42			
Ordnance Compounds				
1,3,5-Trinitrobenzene	3.35			
2,4,6-Trinitrotoluene	1,830	21.8	1.87	
2,4-Dinitrotoluene	5.69			

The three ordnance compounds (1,3,5-trinitrobenzene, 2,4,6-trinitrotoluene, and 2,4-dinitrotoluene) were found to pose risks to the vole. Methods for determining bioconcentration factors (BCFs) were not developed using ordnance compounds and, thus, may not apply. However, ordnance compounds were found at concentrations that would require substantial changes in the BCFs to reduce the HQ to less than 1.0.

Thus, the ordnance compounds may pose threats to small mammalian herbivores and carnivores. The compound 2,4,6-trinitrotoluene was found at such an elevated concentration around the burn trench that deer using the area less than 1 percent of the time still would receive doses that substantially exceed HQs of 1.0.

7.3 UNCERTAINTY ANALYSIS

Sources of uncertainty identified in this risk assessment are summarized in Table 16. For each source of uncertainty, the following are noted: the possible effect on the risk

Table 16
Summary of Uncertainties in the Risk Assessment Approach
and Site-Specific Characteristics

Source of Uncertainty	Direction ^a	Magnitude ^b	Action or Result
Data Evaluation			
Identification of COPCs present at the sites	-	1	Used site-specific information to develop sampling work plan and focus sampling efforts
Quality of analytical data	+/-	1	Used quality-assured data
Exposure Assessment			
No attenuation of chemical concentrations	+	1	Conservatively assumed that no attenuation would take place
Exposure assumptions	+/-	2	Used standard default exposure assumptions and evaluated average and RME individuals
Experimental dermal absorption rates	+/-	2	Preferentially used experimentally derived values
Theoretical dermal absorption rate	+/-	3	Evaluated theoretical dermal absorption rates for comparison
Toxicity Assessment			
Failure to include all chemicals because of lack of toxicity values	-	2	Used surrogate toxicity values where appropriate
Extrapolation from animal studies to human toxicity	+	3	Used conservative approach incorporating safety factors and upper-bound estimates
Lack of chemical-specific dermal toxicity values	-	2	Used unadjusted oral toxicity values as surrogates for dermal toxicity values
Risk Characterization			
Assumption of additive interactions	+/-	2	Assumed additivity of risks
Site-Specific Uncertainties			
Future development of the site for industrial or residential purposes	+	3	Assumed that development could occur despite site's designation as Category III wetlands, a classification that would severely restrict any on-site development
Future site use (e.g., residential use of the shallow aquifer as a drinking water source)	+	2	Assumed that future residential development would occur
Delineation of hot spot	+/-	1	Used statistical approach to verify accuracy of hot spot delineation
Grouping of samples for sitewide evaluation	+	2	Evaluated main area, hot spot, and sitewide data sets for comparison
Use of biokinetic model (i.e., calculating total risk rather than incremental risk)	+	1	Used model with standard default assumptions

^aDirection of effect: + = potentially overestimate risk
- = potentially underestimate risk

^bMagnitude of effect 1 = small effect on risk estimates
2 = medium effect on risk estimates
3 = large effect on risk estimates

Notes:

COPC - chemical of potential concern
RME - reasonable maximum exposure

estimate (i.e., underestimation or overestimation), the degree of such effect, and the steps taken to mitigate the uncertainty.

7.3.1 Data Evaluation

COPCs were identified by using the analytical data from the RI. Confidence in the results presented in the risk characterization depend on the quality of the analytical data obtained during the RI. All analytical data used in the risk assessment were validated to ensure accuracy. Quality assurance aspects of the environmental sampling data were discussed in Section 4.0 of the RI/FS (URS 1993). In general, most analytical methods produce results with an accuracy range of 10 to 20 percent.

Risk estimates presented for the sitewide evaluation may be biased high, because a higher density of samples was obtained from the hot spot than from the main area. This overweights the samples from the hot spot and results in exposure-point concentrations that are biased high.

Sample station distribution and coverage indicate that Site D is well characterized for the nature and extent of chemical distribution. However, there is a lack of data for the intermediate and sea-level aquifers.

7.3.2 Exposure Assessment

Several uncertainties associated with the exposure assessment affect the risk estimates, the most important of which are summarized as follows:

- For the purposes of statistical calculations, quantitation limits for undetected values were divided by two (in cases where the chemical was detected at least once in that medium). This practice may underestimate or overestimate the true average value.
- Although current exposure levels are based on measured concentrations in the media of concern, these values are uncertain because of limited sampling and analytical variation. To account for this, the 95 percent upper confidence limit (UCL) of the mean concentration values and the average values were used in dose calculations. Using the 95 percent UCL in risk assessments is likely to result in an overestimate of the actual average dose.

- Chemical concentrations that could occur under the future land-use scenario are highly uncertain. Chemical concentrations in soil to a depth of 12 feet below ground surface were included in the data set for future land use. The 95 percent UCL of the mean of the soil concentrations over the depth of 0 to 12 feet below ground surface may result in an underestimate or overestimate of actual dose.
- Chemical concentrations in all media for future use were assumed to be the same as current concentrations, with no adjustment due to dilution, biodegradation, or volatilization. This assumption is reasonable for inorganic COPCs (metals); however, for organic COPCs it may result in an overestimate of site risks.
- Dermal uptake of chemicals from soil is difficult to estimate because the value depends on both chemical-specific characteristics of contaminants and the soil at the site, which affects the extent of elemental fixation, desorption, and adsorption to soil particles. The absorption values used to estimate dermal uptake, particularly when no chemical-specific values are available, are highly uncertain, leading to an overestimate or underestimate of the dose.

The risk estimates presented in the risk characterization section of the RI/FS were calculated using 6 percent dermal absorption for all chemicals. The risks were recalculated using 50 percent dermal absorption for 2,4,6-trinitrotoluene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, 1,3,5-trinitrobenzene, and RDX, whereas all other parameters remained the same.

The 6 percent dermal absorption value was based on experimental data available for dermal absorption evaluations. This was the highest dermal absorption value reported under conditions similar to actual human exposure. The 50 percent value is based on a theoretical value assumed for compounds with low K_{ow} s and low dimensionless Henry's Law constants. All risk estimates calculated using dermal exposure values should be considered highly uncertain because of the paucity of data available on chemical-specific dermal absorption rates. Both approaches to evaluating dermal exposure (i.e., the experimental and theoretical approaches to determining dermal absorption values) result in dermal absorption values

that have not been scientifically validated and may result in an overestimation or underestimation of actual exposure.

- The permeability constants used in the derivation of dermal uptake in water are not available for all chemicals identified as COPCs and must be calculated. This may lead to an overestimate or underestimate of the dose for these chemicals. According to EPA's *Dermal Exposure Assessment: Principles and Applications*, preliminary testing showed the dermal dose resulting from a 10-minute shower exceeds the dose associated with drinking 2 L/day for a number of pollutants: "For the fastest penetrating chemicals the dermal dose was predicted to exceed the ingested dose by about two orders of magnitude. . . This seems counterintuitive and raises concerns that the model may be overly conservative. Lack of data makes validation of the model very difficult." (U.S. EPA 1992).

Most of the assumptions in the exposure assessment involved use of default values of standardized risk assessments recommended for EPA Region 10 (U.S. EPA 1991a). Uncertainties regarding exposure assumptions stem from the natural variabilities of parameters such as body weight or soil ingestion rate, as well as from insufficient data on the distribution of these parameters.

7.3.3 Toxicity Assessment

EPA policy states, ". . . as a matter of science policy, the study of the most sensitive species (the species showing a toxic effect at the lowest administered dose) is selected as the critical study for the basis of the RfD" (U.S. EPA 1989). This may overestimate or underestimate the actual risks to humans because of the lack of empirical human toxicity data.

The prediction of potential human health effects likely to occur following exposure to a given dose of a chemical is imprecise because of the many uncertainties in toxicological information on dose-response relationships. The quantity of toxicity information for the chemicals evaluated is typically limited, with correspondingly varying degrees of uncertainty associated with the calculated toxicity values.

Sources of uncertainty associated with toxicity values include the following:

- Using dose-response information from effects observed at high doses to predict the potential adverse health effects from exposure to the low levels expected from human contact with the agent in the environment
- Using dose-response information from short-term exposure studies to predict the effects of long-term exposures and vice versa
- Using dose-response information from animal studies to predict effects in humans
- Using dose-response information from homogeneous animal populations to predict the effects likely to be observed in a general population consisting of individuals with a wide range of sensitivities

Uncertainty factors for most of the RfD values are in the range of 100 or 1,000, indicating considerable uncertainty regarding the actual value of the RfD. For example, the uncertainty factor for oral RfDs for 2,4,6-trinitrotoluene is 1,000. This high uncertainty factor allows for uncertainties in laboratory animal to human dose extrapolation, interindividual sensitivity, subchronic to chronic extrapolation, and lowest observed adverse effects level to no observed adverse effects level extrapolation. On the other hand, the uncertainty factors for the oral RfDs for arsenic, barium, manganese, and silver are less than 10, indicating little uncertainty regarding the actual values for these RfDs.

Two of the carcinogens (cancer-causing chemicals) evaluated in the human health risk assessment (arsenic and chromium VI) are classified as Group A, known human carcinogens. There is little uncertainty regarding the carcinogenicity of these chemicals in humans.

Most of the remainder of the carcinogens are classified as Group B2, probable human carcinogens. Whereas there is no evidence of carcinogenicity in humans, there is sufficient evidence in animals. There are a number of uncertainties regarding evidence of carcinogenicity based on animal tests. One is the use of maximum tolerated doses that cause cellular damage, which increases the rate of cell growth during repair processes. High rates of cell growth tend to increase the potential for carcinogenic effects as a result of the exposure. Another source of uncertainty is the assumption that

all chemicals that are carcinogenic in animals are also carcinogenic in humans. For chemicals classified as Group B2, lack of evidence of carcinogenicity in humans results in considerable uncertainty in the cancer risk estimates.

The assumption that response is linear with respect to dose and that there is no threshold for induction of cancer are important sources of uncertainty. Current theories suggest that carcinogens may act by several different mechanisms, which could result in more than one type of dose-response curve. Currently, however, data are inadequate to support more detailed assumptions regarding dose-response. The uncertainties associated with carcinogenic slope factors (CSFs) make the greatest contribution to the total uncertainty of a cancer risk estimate.

The CSF for benzo(a)pyrene was used as a surrogate for all polycyclic aromatic hydrocarbon (PAH) compounds that are considered carcinogenic. Because benzo(a)pyrene may be the most potent carcinogenic PAH, aggregating carcinogenic PAHs in this fashion may serve to overestimate risks. However, until more toxicity data are available on these contaminants, it is not possible to conduct more chemical-specific evaluations.

Risks associated with dermal contact with soils were evaluated for only a limited number of contaminants. Because metals are not easily absorbed through the skin, the dermal route was not evaluated for metals. In addition, the uncertainty concerning dermal RfDs and CSFs is high because of the lack of chemical-specific dermal toxicity information.

No RfD or CSF is currently available for lead. Therefore, the LEAD5 model was used to evaluate potential exposure to lead. This model provides a conservative estimate of risk because it evaluates exposure to the most sensitive subpopulation.

7.3.4 Risk Characterization

The factors that contribute uncertainty to the estimates of exposure concentrations, daily intakes, and toxicity information also contribute uncertainty to the estimates of cancer and noncancer risks. These factors include the following:

- Chemicals not included
- Exposure pathways not considered

- Derivation of exposure-point concentrations
- Intake uncertainty
- Toxicological dose-response and toxicity values

When values for cancer and noncancer risk are summed across chemicals, it is assumed that the chemical-specific carcinogenic and noncarcinogenic effects are independent and additive. Actually, these effects may interact to produce a less-than-additive effect (antagonistic) or a more-than-additive effect (synergistic). Unfortunately, data on chemical interactions are lacking for most chemical mixtures. In the absence of mixture-specific toxicity data, the assumption of additivity is a standard approach. This may result in an overestimate or underestimate of the cancer and noncancer risks.

The standard approach for evaluating potential health risks at a site is to calculate the incremental risks (i.e., the risks attributable to site-related contamination and not the risks attributable to background sources). The results of the LEAD5 model take into account other sources of lead (e.g., lead present in food). The model provides an estimate of the blood lead concentration resulting from background and site exposure to lead. This may lead to an overestimation of risk.

Elevated human health risks were predicted for metals in groundwater. These risks are considered representative of background, and exposure is not likely for the following reasons:

- The history of the site indicates that the COPCs expected to contribute most of the risk are ordnance compounds and semivolatile organic compounds. No information exists to indicate that the metals in groundwater are attributable to site activities.
- The sea-level aquifer is used in the region for drinking water. Any future drinking water at the site will most likely be obtained from this aquifer.
- Concentrations of metals in groundwater at Site D are comparable to site background and regional background (i.e., Kitsap County) concentrations.

8.0 REMEDIAL ACTION OBJECTIVES

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, may present a hazard to human health or the environment.

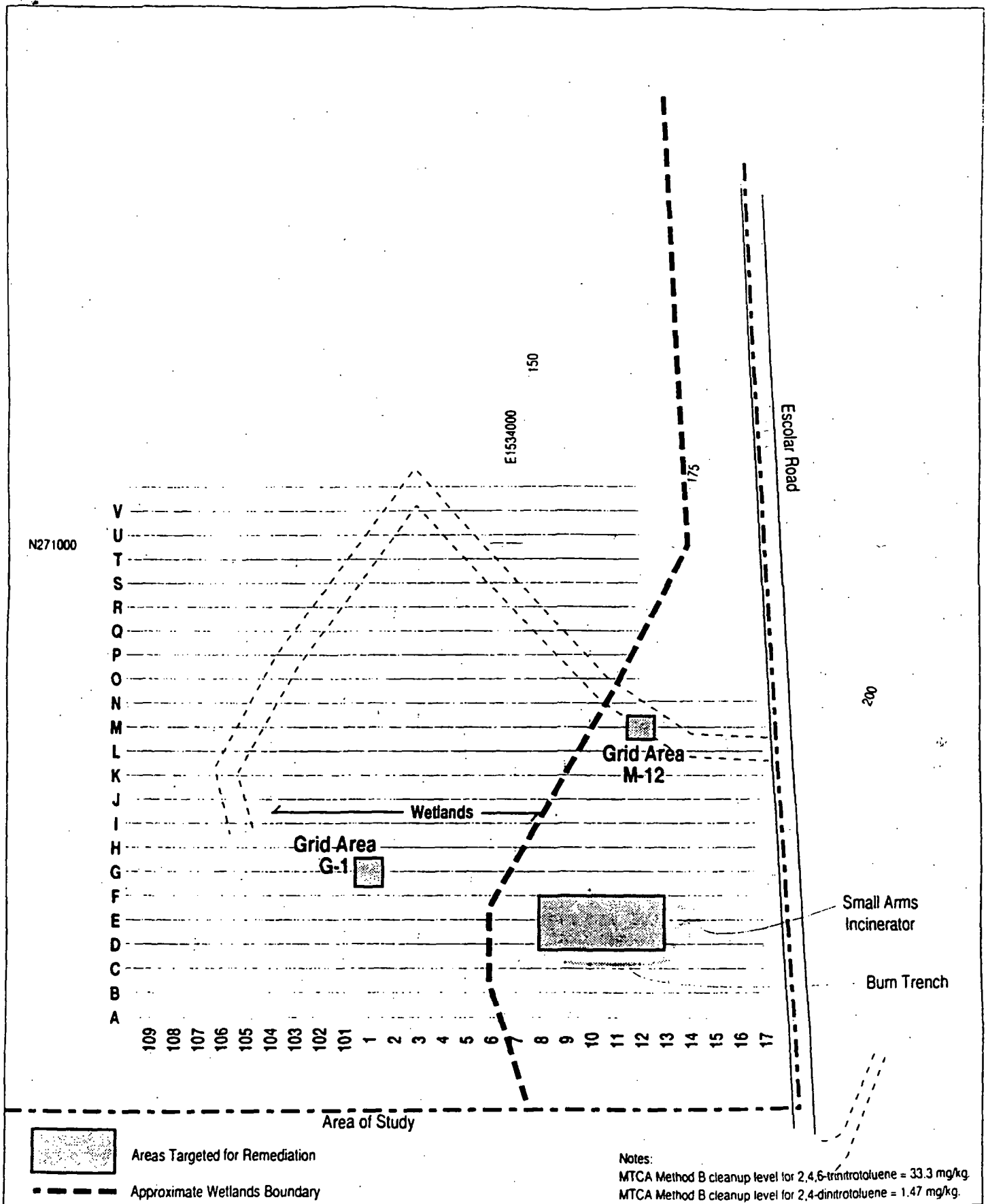
The results of the baseline risk assessment indicate some human health risk to current industrial workers, hypothetical future industrial workers, and hypothetical future residents. Potential ecological effects on small burrowing mammals and deer are predicted if soil contamination is unabated. Based on the risk assessment results, soil contamination at Site D exceeds established health-based thresholds. Consistent with the EPA's NCP and EPA policy, remedial action is warranted to address these potential risks to human health and the environment and to address those areas where chemicals exceed state standards. The following sections present the remedial action objectives (RAOs) for soil, surface water, and groundwater at Site D.

8.1 SOILS

The human health risk assessment identified excess carcinogenic risks exceeding 1×10^{-6} and excess non-carcinogenic hazard indexes exceeding 1.0 associated with COPCs in soil. The compounds 2,4,6-trinitrotoluene and 2,4-dinitrotoluene are the COPCs present in the highest concentrations and quantities in soil and contribute more than 70 percent of the total excess cancer risk at Site D, based on the future residential scenario. Exposure to 2,4,6-trinitrotoluene in soil accounts for greater than 95 percent of the total incremental noncarcinogenic risks. The exposure routes of concern are ingestion and dermal contact with soil. The ecological risk assessment concluded that the compounds 1,3,5-trinitrobenzene, 2,4,6-trinitrotoluene, and 2,4-dinitrotoluene may pose risks to small mammals and the black-tailed deer.

The ordnance compounds of concern were detected in surface and subsurface soils in the burn trench area in the top 3 feet of the soil column and in surface soil at grid locations G-1 and M-12 at concentrations that pose a significant risk to human health and the environment and exceed state cleanup criteria (Figure 12).

The RAO identified for soils at Site D is to prevent unacceptable current and potential future risks to human health and the environment that are posed by ingestion and



CLEAN
COMPREHENSIVE LONG-
TERM ENVIRONMENTAL
ACTION NAVY

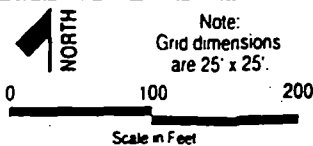


Figure 12
Areas Targeted for Remediation

CTO 0039
OPERABLE UNIT 6
SUBBASE, Bangor
ROD

dermal contact with 2,4,6-trinitrotoluene and 2,4-dinitrotoluene. Response actions to achieve the RAO for soils include treatment of the soils to remove these ordnance compounds.

In developing the remedial goals for soils, consideration was given to the potential impacts of the remediation on the environment at Site D. Washington State Model Toxics Control Act (MTCA) Method B cleanup levels for 2,4,6-trinitrotoluene were applied for the entire site because the concentration of 2,4,6-trinitrotoluene exceeds MTCA Method B cleanup levels in two distinct areas of contamination. However, 2,4-dinitrotoluene is widely distributed across the site at concentrations exceeding MTCA Method B cleanup levels. Approximately 1.4 acres are potentially affected within the wetlands boundary. Therefore, a remedial action to attain MTCA Method B cleanup levels for 2,4-dinitrotoluene within the wetlands would result in significant damage to the existing wetlands ecosystem. In keeping with MTCA requirements (WAC 173-340-706), MTCA Method C cleanup levels will be applied to the cleanup of 2,4-dinitrotoluene within the wetlands boundary to minimize ecological damage to the wetlands.

The following remedial goals have been defined for soils at Site D:

- Remediate all soils at Site D that contain 2,4,6-trinitrotoluene at concentrations exceeding the MTCA Method B cleanup level (33.3 mg/kg).
- Outside the wetlands boundary, remediate soils that contain 2,4-dinitrotoluene at concentrations exceeding the MTCA Method B cleanup level (1.47 mg/kg). Within the wetlands boundary, apply the MTCA Method C cleanup level (58.8 mg/kg) to 2,4-dinitrotoluene.
- For all soils that are remediated, attain MTCA Method B cleanup levels for 2,4,6-trinitrotoluene and related ordnance compounds, including 2,4-dinitrotoluene and 2,6-dinitrotoluene. The soil treatment levels are presented in Table 17.

Attaining the remedial goals for ordnance compounds in soils will reduce the site-wide reasonable maximum exposure concentrations such that excess carcinogenic risks to human health will be in the 10^{-6} range, and excess noncancer hazard indexes will be less than 1.0. Residual human health risks in soils will be primarily attributable to remaining ordnance concentrations in soils and concentrations of PAH compounds detected in sediments on site and upgradient of Site D.

Table 17
Soil Treatment Levels for 2,4,6-Trinitrotoluene and
Related Ordnance Compounds

Compound	MTCA Method B Cleanup Level (Corresponds to 1.0×10^{-6} Cancer Risk ^{a,b}) (mg/kg)
2,4,6-Trinitrotoluene	33.3
2,4-Dinitrotoluene	1.5
2,6-Dinitrotoluene	1.5
Nitrotoluene ^c	800
1,2-Dinitrobenzene	32
1,3-Dinitrobenzene	8
1,4-Dinitrobenzene	32
Trinitrobenzene ^d	4
Nitrobenzene	40

^aCumulative risk from all ordnance compounds remaining in treated soil shall not exceed 1.0×10^{-5} .

^bRisk calculated from MTCA Method B equations

^cIncludes all isomers

^dNoncarcinogen, i.e., cleanup level based on hazard index of 1.0

Hazard quotients for ordnance compounds will be reduced to less than 1.0 for all ecological receptors except the Townsend's vole. The hazard quotient for the Townsend's vole will be reduced approximately by a factor of 100, with the residual risk being attributed mainly to 2,4,6-trinitrotoluene. Applying the MTCA Method C cleanup level to 2,4-dinitrotoluene in the wetlands boundary will also contribute to the residual risk to the Townsend's vole.

Figure 12 shows the areas at Site D in which the concentrations of ordnance compounds in surface soil exceed the remedial goals. Based on these objectives, 880 cubic yards (1,200 tons) of soil will require remediation. The area near the burn trench is approximately 60 by 125 feet and will be excavated to a depth of 2 to 3 feet. The small areas at grid locations G-1 and M-12 are assumed to be approximately 25 by 25 feet and will be excavated to a depth of 1 foot. The excavation depth estimates are based on the

results of subsurface borings. Actual excavation limits at any given location will be based on confirmation sampling during excavation.

8.2 SURFACE WATER

The human health and ecological risk assessments did not identify significant risk associated with COPCs in surface water. However, arsenic, copper, mercury, thallium, and zinc exceeded regulatory criteria in surface water samples collected from Site D. As discussed in Section 6.0, each of these chemicals exceeded in one or two samples out of 32 samples collected. Arsenic also exceeded regulatory criteria in surface water samples collected upgradient of Site D.

Under MTCA, Method B cleanup levels are established to be at least as stringent as concentrations established under state and federal laws. Thus, exceedances of the Washington State Water Quality Standards (WAC 173-201A) and Clean Water Act Ambient Water Quality Criteria (33CFR330) are considered to be exceedances of MTCA Method B surface water cleanup levels.

No source has been identified for the exceedances of MTCA Method B cleanup levels for metals in Site D surface water. Of these metals, only arsenic was detected in soil at concentrations exceeding MTCA Method B soil cleanup levels, in three out of 74 samples. The locations of the arsenic exceedances in soil do not correspond to the locations of the arsenic exceedances in surface water. Stormwater runoff from Escolar Road may contribute to the detected concentrations of metals in surface water at Site D. Arsenic, copper, lead, and zinc have been shown to be present at elevated levels in stormwater runoff (Metro 1982).

Wetlands are known to remove heavy metal pollutants in surface water (Chan 1982, Greeson 1979). Removal mechanisms include sedimentation, adsorption, filtration, and vegetative uptake. These mechanisms likely occur at Site D, as evidenced by the fact that none of the metals detected in Site D surface water exceeded MTCA Method B cleanup levels in downgradient surface water.

Lead and bis(2-ethylhexyl) phthalate exceeded regulatory criteria in surface water samples collected downgradient or cross-gradient from Site D. As discussed in Section 6.0, each of these chemicals exceeded regulatory criteria in one or two samples out of 32 samples collected. Lead and bis(2-ethylhexyl) phthalate do not appear to be related to

site activities. Dissolved lead was not detected in Site D surface water and bis(2-ethylhexyl) phthalate did not exceed MTCA Method B cleanup levels on site. Other sources may exist for the detected cross-gradient and downgradient exceedances, or the bis(2-ethylhexyl) phthalate may have been introduced in the samples as a laboratory contaminant. Since the affected off-site sampling stations (DSW-06, DSW-08, and DSW-09) receive runoff from areas outside of the study area, the single detection of lead and the two exceedances of bis(2-ethylhexyl) phthalate in off-site surface water cannot be attributed to Site D.

In summary, active remediation of surface water at Site D to address exceedances of MTCA Method B cleanup levels is not practicable for the following reasons:

- No COPCs in surface water were identified in the human health or ecological risk assessments as posing significant risks (URS 1993).
- No source area has been identified for the metals found in Site D surface water, although stormwater runoff from Escolar Road may contribute to the metals concentrations.
- No transport of metals is occurring from Site D to downgradient surface water. The wetlands area of Site D provides natural attenuation of metals concentrations.
- Active remediation within the wetlands, where the majority of surface water regulatory exceedances occurred, is likely to cause loss of habitat and greater short-term and long-term environmental risk compared to current risks.

The RAO identified for surface water at Site D is to prevent migration of metals from Site D surface waters in quantities that may adversely affect ecological receptors in downgradient surface waters. Because the Site D wetlands currently attenuate the metals concentrations, the response actions for surface water are limited to institutional controls (specifically confirmation sampling). However, if the results of the confirmation sampling indicate that regulatory criteria are exceeded in downgradient surface waters due to transport of contaminants from Site D, response actions including active remediation will be considered, if feasible.

8.3 GROUNDWATER

8.3.1 Perched Aquifer

Groundwater in the perched aquifer is not a potential future source of drinking water. The human health and ecological risk assessments concluded that it does not pose unacceptable risks when it is manifested as surface water through seeps. Therefore, no regulatory criteria are exceeded and no RAOs are identified for groundwater in the perched aquifer.

8.3.2 Shallow Aquifer

The human health risk assessment concluded that risks due to ingestion or inhalation of shallow aquifer groundwater are almost entirely due to naturally occurring concentrations of inorganics. For organic compounds, regulatory criteria were exceeded in the shallow aquifer for benzene in one sample upgradient of Site D, for tetrachloroethene in one sample upgradient and one sample downgradient of Site D, and for heptachlor in one sample within Site D. Methylene chloride and bis(2-ethylhexyl) phthalate, common laboratory contaminants, exceeded regulatory criteria in 5 out of 26 samples and 3 out of 26 samples, respectively. No sources for the exceedances have been identified. Further characterization of the shallow aquifer is warranted to address these exceedances of regulatory criteria. Accordingly, the RAO established for the shallow aquifer is to prevent potential future risks to human health that may be caused by ingestion or inhalation of COPCs in shallow aquifer groundwater. Response actions to meet the RAO include:

- Short-term monitoring for volatile organic compounds (VOCs) in the shallow aquifer to verify exceedances of health-based criteria
- Further characterization of the shallow aquifer to determine the nature and extent of contamination, if confirmed by the short-term monitoring
- If exceedances of health-based criteria are confirmed, active remediation of shallow groundwater will be considered.

9.0 DESCRIPTION OF ALTERNATIVES

Three areas at Site D have concentrations of ordnance compounds in surface soil that require remedial action. The principal applicable or relevant and appropriate requirement (ARAR) for these remedial actions is MTCA, which lists cleanup standards. Three alternatives were evaluated as possible remedial actions.

9.1 ALTERNATIVE 1: NO ACTION

Alternative 1 is included for comparison purposes under CERCLA. This alternative would not require any action. No treatment, storage, or containment of waste would occur.

Monitoring would be conducted for the chemicals of concern in groundwater in the shallow aquifer and in surface water. The monitoring program would consist of the following components:

- Confirmation sampling of on-site and downgradient surface water for metals would be conducted to assess any transport of surface water contaminants from Site D.
- Short-term monitoring for VOCs in the shallow aquifer would be conducted, using existing monitoring wells, to confirm previous exceedances of health-based criteria. If confirmed, long-term monitoring for VOCs in the shallow aquifer would be conducted.

CERCLA requires a review at least every 5 years if the selected remedial action results in some untreated contamination. This review is also required under MTCA (WAC 173-340-420) because exceedances of Method B cleanup levels will remain on site. The reviews are conducted to ensure that human health and the environment are protected (CERCLA, Section 121). The results of the review would be used to determine whether additional ongoing monitoring is required. A detailed monitoring program would be developed in the remedial design.

Alternative 1 does not sufficiently protect human health or the environment, nor does it meet state and federal regulations for Site D. It does not remove or remediate potential

contaminants detected in the surface soils at Site D and, therefore, results in a risk to human health and the environment.

9.2 ALTERNATIVE 2: INCINERATION

Incineration is a proven technology that would permanently destroy the highest concentrations of contaminants at Site D, thereby protecting human health and the environment. This alternative includes excavation of approximately 1,200 tons of contaminated soils with conventional excavation equipment, testing of the soils below the excavation to verify removal of contaminants to an acceptable level, on-site incineration, testing of incinerated soils to confirm effectiveness, and replacement of the incinerated soils in the excavation. The disturbed area would then be covered with clean topsoil, graded, and revegetated. Monitoring of groundwater and surface water would be required. The components of Alternative 2 are described in detail in the following sections.

9.2.1 Excavation

A detailed excavation plan would be developed before soil removal has started. The plan would describe the configuration and quantity of contaminated material (including soil, debris, vegetation, etc.), the methods to be used to excavate the soil, the methods to be used for staging and stockpiling the soils, the methods for loading the haul trucks, decontamination procedures, and the requirements for personnel protection and health and safety monitoring. The excavation plan would include an environmental protection plan.

Sampling would be performed during excavation to ensure that all contaminated soils exceeding the RAOs are removed and remediated. The excavation plan would include a verification sampling and data analysis plan defining statistical methods to verify attainment of RAOs. Appropriate statistical methods would be used to determine the required number of verification samples. The actual number of samples would vary based on field conditions.

Proper erosion and drainage controls would be implemented during on-site remedial action work to protect any wetlands. Disturbed areas would be restored after the treatment is complete.

9.2.2 Stockpiling

A staging area would be constructed on or near Site D for excavated soils. The actual location of the staging area would be verified in the remedial design. Soils awaiting treatment would be staged in bermed and lined stockpiles in the staging area.

9.2.3 Process Description

A mobile rotary kiln incinerator would be mobilized to the site. The incineration process uses a controlled, enclosed environment to reduce the levels of contaminants in the soils by combusting the soils at high temperatures (approximately 1,600 to 2,000°F). The process permanently destroys organic contaminants, converting them into stable inorganic compounds such as carbon dioxide and water.

Incineration involves the following basic steps:

- Contaminated soil is fed into the incinerator as a fuel source (typically with an auxiliary fuel)
- Soils are burned, destroying organic compounds and yielding residual products in the form of dust and gases
- Treated soils are cooled and stockpiled for use as backfill
- Residual gases are cooled, cleaned, and released to the atmosphere

Incineration would provide nearly complete destruction of ordnance compounds. Possible treatment residuals from incinerator operations include dust and/or scrubber water from the off-gas treatment system. Treatment residuals generated from the incinerator would be analyzed and disposed of in accordance with applicable regulations.

9.2.4 Operating Parameters

- **Site Requirements**

Sufficient area is needed for the incineration system, the feed and auxiliary fuel staging area, and the treated soil stockpile. In addition, space is required for decontamination, spare parts storage, and other auxiliary equipment. Portions of the site may be graveled

and others covered with asphalt. A surface area of approximately 0.5 acre would be required for the incineration site. Construction of access roads to the incineration site may be necessary. Fencing and signs would be required around the treatment site to limit access.

Utility requirements for a mobile incinerator include a continuous water supply and electrical service.

- **Backfilling of Treated Soils**

The treated soil would be tested for ordnance compounds to verify the effectiveness of the treatment in achieving RAOs and treatment standards, and then used to backfill the excavated areas. Treated soil would be devoid of any organic content and would not be conducive to plant growth. Therefore, the disturbed area would be covered with clean soil. Additional clean fill may be required to return the area to natural contours under the incineration alternative because of an approximate 25 percent reduction in volume. The area would be revegetated with native plants.

The treatment system would be removed and the treatment area returned to natural contours and revegetated. Any access roads required for construction of the treatment system, along with the existing access road constructed during the RI at Site D, would be removed and returned to natural contours and revegetated.

- **Implementation Time**

After completion of the remedial design and construction of necessary facilities, the incineration process is expected to take approximately 2 weeks.

9.2.5 Incineration ARARs

Incineration will require meeting the substantive permit requirements, including siting and performance criteria. Requirements are set forth in the Clean Air Act (40 CFR 61) and WAC 173-460, and in the Puget Sound Air Pollution Control Agency regulations.

Excavation and backfilling would be performed in accordance with the health and safety requirements of the Occupational Safety and Health Administration (OSHA) (29 CFR 1910 and 1926) and the Washington Industrial Safety and Health Administration (WISHA) (WAC 296-62 Part P). Under typical conditions, no respiratory protection

would be required; however, the contractor would use appropriate dust control methods and would monitor for airborne particulates. Fugitive dust emissions would be regulated by the Puget Sound Air Pollution Control Agency.

The chemical and historical information from the RI indicates that excavated soil and debris would not be designated as a dangerous or hazardous waste based on the evaluation criteria set forth in the Washington State Dangerous Waste Regulations (WAC 173-303) and the Resource Conservation and Recovery Act (RCRA) regulations (40 CFR 261).

9.2.6 Monitoring and Review

Under Alternative 2, the monitoring program would consist of the following components:

- Confirmation sampling of on-site and downgradient surface water would be conducted following soil remediation. Surface water samples would be analyzed for metals to address previous metals exceedances and for ordnance compounds to verify that ordnance compounds were not mobilized during soil remediation activities. If the results of the confirmation sampling indicate that regulatory criteria are exceeded in downgradient surface waters due to transport of contaminants from Site D, response actions including active remediation would be considered.
- Short-term monitoring for VOCs in the shallow aquifer would be conducted, using existing monitoring wells, to confirm previous exceedances of health-based criteria. If confirmed, further investigations to characterize the source and extent of VOCs in the shallow aquifer would be conducted. Once characterized, active remediation of the shallow aquifer would be conducted, if necessary and feasible.

A review would be conducted within 5 years of implementation of the remedy to evaluate the effectiveness of the remedy and to ensure that human health and the environment are protected. The results of the review would be used to determine whether additional actions or ongoing monitoring is required. A detailed monitoring program would be developed in the remedial design.

9.2.7 Land-Use Restrictions

Alternative 2 does not include deed restrictions or other administrative limitations on future land use. Existing wetlands laws would prevent future development of Site D wetlands.

9.3 ALTERNATIVE 3: COMPOSTING

Composting is an innovative technology that would permanently destroy the highest concentrations of contaminants at Site D, thereby protecting human health and the environment. This alternative includes excavating approximately 1,200 tons of contaminated soil with conventional excavation equipment, testing the soil below the excavation to verify removal of contaminants to an acceptable level, on-site composting, testing the composted soils to confirm effectiveness, and replacing the composted soils in the excavation. The disturbed area would then be covered with clean topsoil, graded, and revegetated. Monitoring of groundwater and surface water would be required. The components of Alternative 3 are described in detail in the following subsections.

9.3.1 Excavation

Excavation would be conducted as described under Alternative 2.

9.3.2 Stockpiling

Stockpiling would be conducted as described under Alternative 2.

9.3.3 Process Description

Composting is a biological treatment process by which toxic organics are biodegraded to less toxic organic and inorganic by-products and heat energy. The heat energy is then trapped within the compost matrix, enhancing the microbiological growth rate and thus the biodegradation rate. Composting is a well-developed technology used commercially to treat garbage, yard and agricultural waste, and wastewater sludges.

Composting can be accomplished by three methods: static pile, mechanically agitated in-vessel (MAIV), and windrow. Static composting was rejected during the screening process of the FS on the basis of effectiveness. Windrow and MAIV composting are

methods that have been proven effective at treating ordnance-contaminated soils (Weston 1993). Windrow composting has been shown to be as effective as, or superior to, MAIV in biodegrading 2,4,6-trinitrotoluene. The primary difference between the two composting systems is the technology level required to maintain operating parameters in order to achieve the desired degradation efficiency. The MAIV method is a highly automated and multistep process with capital and operation and maintenance costs higher than that of the windrow composting process. For these reasons, the windrow technology is the preferred process option for Site D soils.

Components of a windrow composting system include an excavated soil staging area, a material storage area, soil screening and mixing areas, a process water system and electrical service, a front-end loader and dump truck, a treatment pad, a canopy, and a windrow-turning machine.

The first step in the windrow composting process is feed preparation. Before the amendments (additives to promote composting) are added, the excavated soil may need mechanical screening to remove unacceptable debris and large rocks in order to prevent damage to or interference with the composting process. Rocks and debris would be washed to remove any contaminated particulate. The rocks would be returned to the excavated area and other debris would be properly disposed of in an acceptable on-site or off-site location. Wastewater would be collected in a leachate collection system and reused in the composting system to maintain a proper moisture content. Vegetation from the remediation area would be chipped and/or shredded, if necessary, and incorporated into the compost piles.

The most effective and least expensive amendments used in previous treatability studies were manure/alfalfa-based amendments. The exact composition of amendments to be used in composting Site D soils will be determined in the pilot-scale treatability study. The most effective soil loading volumes, as a percentage of total composting volume, range from 10 to 30 percent. Greater soil volume loadings significantly reduce the degradation potential of the ordnance compounds by reducing heat generation. The pilot-scale treatability study for Site D soils being conducted at Site F will verify that heat generated within the windrows is sufficient to maintain optimum temperatures. Any technical concerns identified in the pilot-scale treatability study will be addressed in the remedial design.

The compost mixture would be prepared by adding soil and amendments to a mixing bin. Multiple bins allow the material to be prepared in stages. The mixture would then be

transferred from the bin to a windrow. After a new batch of compost mixture is placed in a row, a windrow-turning machine would pass over the new compost to fluff, aerate, and shape the pile. Once established, the windrow would require periodic turning by the windrow-turning machine.

No treatment residuals, other than the compost mixture itself, would be generated. Treatability studies have indicated that a greater than 99 percent reduction in 2,4,6-trinitrotoluene concentrations can be readily achieved. Degradation products of 2,4,6-trinitrotoluene in the compost mixture, which include monoaminodinitrotoluenes and diaminonitrotoluenes, have limited mobility and significantly lower toxicity than the parent compound.

9.3.4 Operating Parameters

- **Site Requirements**

The composting facility would be sited at SUBASE, Bangor. The primary design parameter for windrow composting is the assumption that the desired degradation will be achieved for each batch after 7 weeks of treatment. This timeframe has been verified in the bench-scale treatability study using soils from Site D. The remediation timeframe will be verified in the pilot-scale study and may affect the size of the treatment area required for window composting. The total area required for windrow composting is estimated at 41,000 square feet.

Utility requirements for the composting system include a continuous water supply and electrical service. Fencing and warning signs would be constructed to limit access to the treatment site.

- **Treatability Study**

In addition to the bench-scale treatability study that has verified the effectiveness of composting, a pilot-scale treatability study will determine the optimal soil-to-amendment ratio, amendment composition, water requirements, and residence times. This information is required for developing design parameters for a final composting treatment facility.

The treated soils would be tested for ordnance compounds to verify the effectiveness of the treatment in achieving RAOs, and then used to backfill the excavated areas. Most materials in the compost amendment, such as the manure, are expected to decompose within the specified treatment time. However, some of the components may not totally decompose during the specified treatment time but are expected to continue to decompose after being placed in the excavated area. This phase of composting is referred to as curing and results in the production of stabilized compost. A stabilized compost requires no additional nutrients to enhance degradation and has a low oxygen demand. Curing would continue at a slow rate after the materials have been placed in the excavation, and the compost would not require continued management. To minimize runoff of excess nutrients from curing compost, the backfilled areas would be covered with clean soil and revegetated with native plants. The soil cover would minimize public and environmental exposure to the compost material.

Upon completion, the treatment system would be removed and the treatment area returned to natural contours and revegetated. Any access roads required for construction of the treatment system, along with the existing access road constructed during the RI at Site D, would be removed and returned to natural contours and revegetated.

After completion of the remedial design and construction of necessary facilities, the expected time to remediate the soils by composting is 8 months. The operation time may vary seasonally and would depend on the soil condition.

Excavation and backfilling would be performed in accordance with the health and safety requirements of the Occupational Safety and Health Administration (OSHA) (29 CFR 1910 and 1926) and the Washington Industrial Safety and Health Administration (WISHA) (WAC 296-62 Part P). Under typical conditions, no respiratory protection would be required; however, the contractor would use appropriate dust control methods and would monitor for airborne particulates. Fugitive dust emissions would be regulated by the Puget Sound Air Pollution Control Agency.

The chemical and historical information from the RI indicates that excavated soil and debris would not be designated as a dangerous or hazardous waste based on the evaluation criteria set forth in the Washington State Dangerous Waste Regulations (WAC 173-303) and the Resource Conservation and Recovery Act (RCRA) regulations (40 CFR 261).

9.3.6 Monitoring and Review

Under Alternative 3, the monitoring program would consist of the following components:

- Confirmation sampling of on-site and downgradient surface water would be conducted following soil remediation. Surface water samples would be analyzed for metals to address previous metals exceedances, and for ordnance compounds to verify that ordnance compounds were not mobilized during soil remediation activities. If the results of the confirmation sampling indicate that regulatory criteria are exceeded in downgradient surface waters due to transport of contaminants from Site D, response actions including active remediation would be considered.
- Short-term monitoring for VOCs in the shallow aquifer would be conducted, using existing monitoring wells, to confirm previous exceedances of health-based criteria. If confirmed, further investigations to characterize the source and extent of VOCs in the shallow aquifer would be conducted. Once characterized, active remediation of the shallow aquifer would be conducted if necessary and feasible.

A review would be conducted within 5 years of implementation of the remedy to evaluate the effectiveness of the remedy and to ensure that human health and the environment are protected. The results of the review would be used to determine whether additional actions or ongoing monitoring is required. A detailed monitoring program would be developed in the remedial design.

9.3.7 Land-Use Restrictions

No deed restrictions or other administrative limitations on future land use are included in Alternative 3. Existing wetlands laws would prevent future development of Site D wetlands.

10.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

The EPA has established nine criteria for the evaluation of remedial alternatives:

- **Overall protection of human health and environment**—whether a remedy provides adequate protection and how risks posed through each pathway are eliminated, reduced, or controlled through treatment engineering controls or institutional controls
- **Compliance with ARARs**—whether a remedy will meet all of the ARARs of other federal and state environmental statutes and/or provide grounds for invoking a waiver
- **Long-term effectiveness and permanence**—the magnitude of residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time once cleanup goals have been met
- **Reduction of toxicity, mobility, or volume through treatment**—the anticipated performance of the treatment technologies that may be employed in a remedy
- **Short-term effectiveness**—the speed with which the remedy achieves protection, as well as the remedy's potential to adversely affect human health and the environment during the construction and implementation period
- **Implementability**—the technical and administrative feasibility of a remedy, including the availability of materials and services needed to implement the chosen solution
- **Cost**—includes capital and operation and maintenance costs
- **State acceptance**—whether, based on its review of the RI/FS and proposed plan, the State concurs with, opposes, or has no comment on the preferred remedy.

- **Community acceptance**—comments received during the public comment period indicate whether the community concurs with the preferred remedy.

The three remedial action alternatives for Site D were evaluated against these criteria. The following sections discuss each of the alternatives in terms of the evaluation criteria.

10.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

10.1.1 Alternative 1

Alternative 1 (no action) does not contribute any additional protection to present and future workers or future residents at Site D, nor does it provide any additional protection to the environment. The contaminant levels at the site, determined by the risk assessment to be above acceptable limits, will remain essentially at current concentrations for more than 10 years. The exposure pathways of concern at the site are dermal contact and ingestion of ordnance-contaminated soils, and ingestion of groundwater from the shallow aquifer. Alternative 1 does not eliminate, reduce, or control exposure to the contaminants and does not meet the RAOs.

10.1.2 Alternative 2

Alternative 2 (incineration) would be effective in protecting human health and the environment. All RAOs would be met by the alternative. Residual risks in treated soils are expected to be below the most stringent of the carcinogenic risk levels deemed acceptable for human exposure. Final concentrations of ordnance compounds in the treated soil are expected to be near zero and below MTCA Method B cleanup values for all ordnance compounds and their degradation products.

Treated soil (void of any organic content) deposited back in the original excavation would not be conducive to plant growth. Therefore, clean topsoil would be placed over the treated soil and the site revegetated and returned to original grade. Adherence to the substantive permitting requirements would ensure that the incineration system is operating safely and effectively. Gases emitted to the atmosphere would be monitored and the system shut down if the incinerator did not meet substantive permit requirements. Occupational risks during construction would be addressed in the project health and safety plan.

Potential human health risks associated with groundwater in the shallow aquifer and potential ecological risks associated with exceedances of regulatory criteria in surface water would be addressed in the monitoring program, and, if necessary and feasible, through active remediation.

10.1.3 Alternative 3

Alternative 3 (composting) would provide for the overall protection of human health and the environment by reducing 2,4,6-trinitrotoluene concentrations in the finished compost to 33 mg/kg or less, and reducing 2,4-dinitrotoluene and 2,6-dinitrotoluene concentrations to 1.47 mg/kg or less. The results of the composting studies indicate that these levels can be achieved. Remediation to these concentrations or less would meet the RAOs. Consequently, human and environmental exposure to high concentrations of ordnance compounds in soils would be reduced to acceptable levels. Following treatment, the compost mixture would be backfilled. Clean soil will be placed over the compost and revegetated to minimize runoff of excess nutrients from curing compost. Occupational risks during construction would be addressed in the project health and safety plan.

Potential human health risks associated with groundwater in the shallow aquifer and potential ecological risks associated with exceedances of regulatory criteria in surface water would be addressed in the monitoring program, and, if necessary and feasible, through active remediation.

10.2 COMPLIANCE WITH ARARS

10.2.1 Alternative 1

Alternative 1 (no action) does not comply with either federal or state ARARs regarding soil remediation. The excess cancer risk posed by direct contact with contaminated surface soils currently present at Site D based on the future residential use scenario is within the acceptable range of 10^{-4} to 10^{-6} stated in the NCP. However, the non-cancer hazard index exceeds 1.0. Concentrations of chemicals in soil exceed the cleanup standards established in MTCA.

10.2.2 Alternative 2

Alternative 2 (incineration) will meet all ARARs as described:

- **Chemical-Specific ARARs**

Incineration is expected to successfully reduce concentrations of ordnance compounds in the excavated soil to below MTCA Method B cleanup levels. Remediation to concentrations below the cleanup levels would meet MTCA's requirement of reducing excess cancer risk to 1.0×10^{-6} or less. Chemical-specific ARARs for groundwater and surface water would be met through monitoring, and, if necessary and feasible, active remediation.

- **Location-Specific ARARs**

Incineration would not affect protected species at SUBASE, Bangor. Remedial actions in potential wetlands areas would be conducted in accordance with the U.S. Army Corps of Engineers' conditions of the Nationwide Permit Program and will, therefore, meet the applicable ARARs.

- **Action-Specific ARARs**

The mobile rotary kiln incineration process would be designed and operated to satisfy all action-specific ARARs.

10.2.3 Alternative 3

Alternative 3 (composting) would meet all ARARs, as described:

- **Chemical-Specific ARARs**

Treatability studies of ordnance composting have shown that composting degrades greater than 99 percent of 2,4,6-trinitrotoluene in soil. Composting would reduce the concentrations of ordnance compounds in the excavated soil to below MTCA Method B cleanup levels. Remediation to concentrations below the cleanup levels would meet MTCA's requirement of reducing excess cancer risk to 1.0×10^{-6} or less. Chemical-

specific ARARs for groundwater and surface water would be met through monitoring, and, if necessary and feasible, active remediation.

- **Location-Specific ARARs**

Composting is not expected to affect protected species of SUBASE, Bangor. Remedial actions in or adjacent to the wetlands area that are conducted in accordance with the U.S. Army Corps of Engineers' conditions of the Nationwide Permit Program will meet the applicable ARARs.

- **Action-Specific ARARs**

The composting system used for Site D would be designed and operated to satisfy all action-specific ARARs.

10.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Under each alternative, surface water confirmation sampling would be conducted to ensure that downgradient surface water is not adversely affected by runoff from Site D. Short-term monitoring would be conducted for VOCs in the shallow aquifer to confirm previous exceedances of health-based criteria. If confirmed, further investigations to characterize the source and extent of VOCs in the shallow aquifer would be conducted. Once characterized, active remediation of the shallow aquifer would be conducted if necessary and feasible (under Alternatives 2 and 3).

10.3.1 Alternative 1

The effectiveness and reliability of Alternative 1 (no action), which includes no new control measures, is extremely low. The long-term magnitude of remaining risk will not be altered under this alternative. Carcinogenic risks will remain above acceptable limits and the potential for direct exposure for future site users remains.

10.3.2 Alternative 2

Alternative 2 (incineration) is an effective method of permanently destroying organics such as the ordnance contaminants at Site D. Because the process destroys all traces of

the contaminants in treated soils, the long-term effectiveness of the alternative is excellent.

10.3.3 Alternative 3

Alternative 3 (composting) is expected to reduce the concentration of ordnance compounds in excavated soil to levels that achieve the RAOs and satisfy MTCA Method B requirements. The residual concentrations in the treated compost are expected to be less than 33.3 mg/kg for 2,4,6-trinitrotoluene and 1.47 mg/kg for 2,4-dinitrotoluene, requiring no additional remediation or long-term management.

10.4 REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

10.4.1 Alternative 1

No treatment methods are employed under Alternative 1 (no action). Therefore, little, if any, reduction in toxicity, mobility, or volume of the on-site contaminants will be achieved.

Natural processes will gradually reduce the toxicity of ordnance-contaminated soils. In situ biodegradation is occurring, as evidenced by the presence of transformation products of 2,4,6-trinitrotoluene; however, the natural degradation rate is slow. Unacceptable levels of contamination are still present at the site 25 years after ordnance incineration and disposal ceased. Ordnance compounds have a high affinity for soil, and surface soil contamination has spread downgradient of the burn trench because of natural erosion and surface water runoff.

10.4.2 Alternative 2

Alternative 2 (incineration) will significantly reduce contaminant toxicity and volume. Organic contaminant mobility will not be an issue after the contaminants are treated. The toxicity and volume of the ordnance contaminants will be reduced by nearly 100 percent through the incineration process. The soil volume will be reduced by approximately 25 percent. Incineration is the most effective alternative in reducing contaminant toxicity.

10.4.3 Alternative 3

Alternative 3 (composting) will permanently reduce the toxicity and mobility of ordnance compounds in the soil. Greater than 99 percent destruction of ordnance compounds is expected. However, the volume of finished compost product will be approximately 100 percent greater than the volume of soils excavated for treatment.

10.5 SHORT-TERM EFFECTIVENESS

10.5.1 Alternative 1

Because no new treatment or construction activities will occur with Alternative 1 (no action), no additional risks would be posed to the environment or to workers or the public.

10.5.2 Alternative 2

After completion of the remedial design and construction of the necessary facilities, the incineration process is expected to take approximately 2 weeks.

No adverse effects on humans or the environment are expected during the incineration remediation process. The incinerator operator may conduct a "trial burn" (or submit performance data that can serve as a substitute for trial burn results) to test the ability of the incinerator to meet all applicable performance standards. The risk to the environment and the public during a trial burn is minimal because of the small quantity of incinerated materials and the short duration of the test.

During excavation, dust would be monitored to protect on-site workers from airborne particulates. Monitoring and corrective actions required to maintain safe levels would be discussed in the health and safety plan. Exposure to dust at the site is not expected to be a significant problem.

Operation of the incinerator would alter the natural conditions of the site because of tree clearing, grading, and construction of an access road. Wetlands may be affected during the excavation/backfilling phases. Disturbed land areas would be reclaimed following project completion.

The incinerator, if operating properly, would be virtually smokeless and odorless. A white vapor, composed mostly of water vapor, would discharge from the stack. Noise from the incineration process is not expected to be significant. Monitoring of emission gases would be required to verify compliance with appropriate standards. A decontamination area would be constructed for workers and equipment to eliminate the potential for off-site transport of contaminants. Fencing and signs would limit access to the treatment area. No protected species are expected to be affected during the remediation.

10.5.3 Alternative 3

After completion of the remedial design and construction of the necessary facilities, the time required to implement Alternative 3 is approximately 8 months. This alternative poses minimum risks to workers or the community during remediation. The site is currently a restricted area and there are no base-related activities in the area except for traffic on Escolar Road. The base is a secured facility. Fencing and signs would limit access to the treatment area.

With a properly designed treatment facility, including leachate collection and containment features, emissions of ordnance compounds from the treatment site are not expected. Care would be taken to ensure that the operation of the windrow turner does not release soil particles from the treatment area. Adequate ventilation would be provided in the treatment area to prevent the buildup of ammonia from the composting process.

Implementing this alternative would alter the natural conditions of the site because of tree clearing, grading, and construction of an access road. Wetlands might be affected during the excavation/backfilling phases. Disturbed land areas would be reclaimed following project completion.

Workers would be required to wear protective gear, follow special handling procedures, and perform monitoring to minimize risk involved with the remediation process. The backfilled compost would pose little or no ecological risk. No protected species are expected to be affected during the remediation.

10.6 IMPLEMENTABILITY

10.6.1 Alternative 1

Technically, Alternative 1 (no action) is implementable. The administrative feasibility, however, is relatively low. Regulatory agencies will probably find Alternative 1 unacceptable.

10.6.2 Alternative 2

The technical and administrative implementability of Alternative 2 (incineration) is good. Incineration use has been demonstrated at other military installations. Fulfilling the substantive permit requirements will require that the owner or operator of the incinerator perform regular inspections and maintenance according to specified schedules. Mobile rotary kiln incinerators are widely available. Several vendors are capable of providing the required incineration services.

10.6.3 Alternative 3

The technical implementability of Alternative 3 (composting) has been proven for ordnance-contaminated soils in pilot studies and with bench-scale studies of Site D soils. Composting is a well-developed technology and is used commercially for treatment of garbage, waste sludge, and yard waste. Additionally, sufficient information and experience is available as a resource for design and operating purposes. A pilot-scale treatability study for windrow composting of Site D soils will verify design parameters. Construction of a windrow composting facility poses no unusual design or construction problems. Composting is readily implemented administratively.

10.7 COST

The estimated capital and operation and maintenance (O&M) costs for each alternative are summarized in Table 18. Net present worth costs are also summarized and are based on 5 years of operations and an assumed annual discount rate of 5 percent. The cost estimates provide an accuracy of +50 percent to -30 percent, in accordance with EPA guidelines.

Table 18
Cost Comparison of Remedial Action Alternatives

Alternative	Capital Cost	Annual O&M Cost	Net Present Worth
No action	\$0	\$16,500	\$75,000
Incineration	\$1,424,000	\$16,500	\$1,499,000
Composting	\$841,000	\$16,500	\$916,000

10.8 STATE ACCEPTANCE

Ecology concurs with the selected remedial action at Site D and has been involved in the development and review of the RI, FS, proposed plan, and ROD. Comments from Ecology have resulted in substantive changes in these documents, and the agency has been integrally involved in determining which cleanup standards apply to contaminated soil under MTCA.

10.9 COMMUNITY ACCEPTANCE

Comments received during the public comment period (January 9 through February 8, 1994) indicate that the public accepted the proposed plan.

11.0 THE SELECTED REMEDY

Based on consideration of CERCLA requirements, the detailed analysis of the alternatives using the nine EPA criteria, and the public comments received, both the EPA and the State of Washington have determined that Alternative 3 (composting) is the most appropriate remedy for OU 6, Site D, at SUBASE, Bangor.

The selected remedy includes the following components:

- Excavating and stockpiling soils containing the highest concentrations of ordnance compounds. All soils at Site D that contain 2,4,6-trinitrotoluene

in concentrations exceeding the MTCA Method B cleanup levels (33.3 mg/kg) will be excavated. Outside the wetlands boundary, soils that contain 2,4-dinitrotoluene in concentrations exceeding the MTCA Method B cleanup levels (1.47 mg/kg) will be excavated. Within the wetlands boundary, the MTCA Method C cleanup level (58.8 mg/kg) will be applied to 2,4-dinitrotoluene.

- Remediating the excavated soils by composting at SUBASE, Bangor. Composting will attain MTCA Method B cleanup levels for 2,4,6-trinitrotoluene and its degradation products, including 2,4-dinitrotoluene and 2,6-dinitrotoluene.
- Backfilling the treated soils in the excavations, covering them with clean soil, and revegetating the affected areas with native vegetation.
- Returning the treatment area and any access roads (including the existing access road at Site D) to natural contours and revegetating them with native vegetation.
- Conducting confirmation sampling of on-site and downgradient surface water. One round of surface water sampling will occur following soil remediation. Surface water samples will be analyzed for metals to address previous metals exceedances and for ordnance compounds to verify that ordnance compounds were not mobilized during soil remediation activities. If the results of the confirmation sampling indicate that regulatory criteria are exceeded in downgradient surface waters due to transport of contaminants from Site D, response actions including active remediation will be considered.
- Conducting short-term monitoring of the shallow aquifer to confirm previous exceedances of health-based criteria. The short-term monitoring in the shallow aquifer will consist of one round of sampling for VOCs using existing monitoring wells. The results of this sampling will be compared to the most restrictive criteria established under the following ARARs: federal MCLs (40 CFR 141); state MCLs (WAC 246-290-310); and MTCA Method B cleanup levels (WAC 173-340-720). If exceedances are confirmed, further investigations to characterize the source and extent of

VOCs in the shallow aquifer will be conducted. Once characterized, response actions including active remediation will be considered.

- Conducting a review of the soil remediation data and the short-term monitoring data to evaluate the effectiveness of the remedy and to ensure that human health and the environment are protected. The review will be conducted within 5 years of commencement of the remedial action. The results of the review will be used to determine whether additional action or monitoring is required.

The selected remedy will protect human health and the environment by achieving the RAOs and soil treatment levels presented in Section 8.0.

12.0 STATUTORY DETERMINATION

Under CERCLA, Section 121, the selected remedies must be protective of human health and the environment, comply with ARARs, be cost effective, and use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduces the volume, toxicity, or mobility of hazardous wastes as their principal element. The following sections discuss how the selected remedy meets these statutory requirements.

12.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The selected remedy will protect human health and the environment by removing and treating the Site D soils that contain ordnance compounds in concentrations above the established MTCA Method B and Method C cleanup levels. The excavated soils will be treated by composting to permanently reduce concentrations of ordnance compounds to below MTCA Method B concentrations. The selected remedy will minimize risks to ecological receptors by removing the highest concentrations of ordnance compounds from Site D, while minimizing the short-term environmental impacts of the remediation on wetlands.

Confirmation sampling of surface water and characterization of shallow groundwater will address potential human health and ecological risks associated with surface water and groundwater. A review will be conducted within 5 years of the commencement of the remedial action to ensure that the remedy continues to provide adequate protection of human health and the environment.

12.2 COMPLIANCE WITH ARARS

The selected remedy of soil treatment by composting, along with monitoring of surface water and perched groundwater and monitoring and characterization of the shallow aquifer, will comply with all state and federal ARARs. Action-specific, chemical-specific, and location-specific ARARs are presented below, along with to-be-considered (TBC) guidance that has been developed to implement ARARS.

12.2.1 Action-Specific ARARs

- **Hazardous Waste Management Act (42 USC 6901 *et seq.*); Resource Conservation and Recovery Act (RCRA), Regulations (40 CFR 260 to 268); Washington State Dangerous Waste Regulations (WAC 173-303)**

These regulations establish the procedures for the designation of waste as hazardous or dangerous. They are applicable for determining handling and disposal requirements for hazardous/dangerous wastes generated during cleanup activities.

- **The Clean Air Act, Section 101 (42 USC 7405, 7601); Washington General Regulations for Air Pollution Sources (WAC 173-400)**

These requirements are applicable to sources of fugitive dust that are generated during the remediation efforts and must be controlled to avoid nuisance conditions.

- **The Puget Sound Air Pollution Control Agency Regulations**

These requirements are applicable to sources of fugitive dust that are generated during the remediation efforts and must be controlled to avoid nuisance conditions.

- **The Occupational Safety and Health Administration (OSHA) standards (29 CFR 1910.1000)**

These standards regulate employee exposure to airborne hazardous substances listed in Tables 2-1-A through 2-3 of the rules. Table 2-1-A of the standards list 2,4,6-trinitrotoluene, 2,4-dinitrotoluene, and 2,6-dinitrotoluene. Table 2-3 provides standards for inert or nuisance dust that could be the result of airborne soil. These standards apply to worker conditions during the excavation and handling of contaminated soil.

- **Federal Occupational Safety and Health Regulations (29 CFR 1926)**

These requirements establish applicable health and safety standards for workers engaged in hazardous waste investigations.

- **State of Washington Occupational Safety and Health Regulations (WAC 296-62, Part P)**

These requirements establish applicable health and safety standards for workers engaged in hazardous waste investigations.

- **Hazardous Materials Transportation Act (49 CFR 171 to 172)**

These regulations are applicable to the transportation of potentially hazardous materials, including samples and wastes.

12.2.2 Chemical-Specific ARARs

- **The State of Washington Hazardous Waste Cleanup—Model Toxics Control Act (MTCA; Chapter 70.105D RCW)**

Establishes requirements for the identification, investigation, and cleanup of facilities where hazardous substances have come to be located as codified in Chapter 173-340 WAC. Soil, surface water, and groundwater cleanup standards established under the MTCA are applicable for determining remediation areas and volumes and compliance monitoring requirements, and are relevant and appropriate for determining treatment standards.

- **Washington Dangerous Waste Regulations (WAC 173-303)**

These regulations are applicable in determining whether excavated soil is considered a dangerous waste for purposes of waste handling and treatment system design and operation.

- **Safe Drinking Water Act MCLs and MCLGs (40 CFR 141)**

The Safe Drinking Water Act establishes maximum contaminant levels (MCLs) and maximum contaminant level goals (MCLGs). The MCL is the maximum permissible level of a contaminant in water that is delivered to any user of a public water system. The MCLG is the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on human health would occur and that allows an adequate margin of safety. MCLGs are nonenforceable. Although the groundwater at Site D is not currently used as a source of drinking water, MCLs should be considered an ARAR for the shallow aquifer.

- **State Board of Health Drinking Water Regulations (WAC 246-290-310)**

The Washington State Board of Health has established MCLs similar to federal MCLs. Because the groundwater in the shallow aquifer at Site D is a potential source of drinking water based on the future residential scenario, state MCLs should be considered an ARAR for the shallow aquifer.

- **Safe Drinking Water Act Health Advisories**

The Safe Drinking Water Act health advisories are classified a "to be considered" guideline for evaluating shallow aquifer groundwater quality at Site D.

- **State of Washington Water Quality Standards for Surface Waters (WAC 173-201A)**

These requirements establish water quality standards for surface waters at Site D.

- **Clean Water Act Ambient Water Quality Criteria for Surface Water (33 CFR-330)**

Chemical-specific numeric criteria have been promulgated for priority pollutants in ambient surface waters. These criteria are applicable to surface waters at Site D.

12.2.3 Location-Specific ARARs

Several ARARs apply to wetlands and the critical habitat at Site D.

- **Executive Order 11990 (40 CFR 6); Clean Water Act, Section 404 (33 CFR 330)**

Executive Order 11990 requires federal agencies to avoid, to the extent possible, the adverse impacts associated with the destruction or loss of wetlands. The responsible party is required to avoid adverse impacts or minimize these impacts if no practical alternative to the action exists (U.S. EPA 1991b). Under Section 404 of the federal Clean Water Act, the Secretary of the Army, acting through the United States Army Corps of Engineers, provides the guidelines for actions that occur in wetlands. The United States Army Corps of Engineers' Nationwide Permit (NWP) program (33 CFR 330) provides the regulations that apply to wetlands. The regulations provide several allowances for activities occurring in wetlands, one of which specifically addresses remedial actions in wetlands.

The allowance 33 CFR 330 (Appendix A[B][38]) is for specific activities required to contain, stabilize, or remove hazardous waste that are performed, ordered, or sponsored by a government agency with established legal or regulatory authority. Court-ordered remedial action plans or related settlements are also authorized by the nationwide permit. Although this allowance provides for remedial actions in wetlands, such activities still must comply with the "Notification" general condition of the NWP (33 CFR 330 Appendix A[C][13]).

- **Endangered Species Act of 1973 (16 USC 1531 *et seq.*; 50 CFR 402); Fish and Wildlife Coordination Act (16 USC 661 *et seq.*)**

Although no known threatened or endangered species have been observed on Site D, eagles have been observed at SUBASE, Bangor. The bald eagle (*Haliaeetus leucocephalus*) is protected by the Endangered Species Act of 1973 and the Fish and Wildlife Coordination Act. Any action that would affect the critical habitat of the bald eagle would be subject to these ARARs.

12.2.4 TBC Guidance

The Washington State Department of Ecology document "Statistical Guidance for Ecology Site Managers" is identified as a TBC in implementing the requirements of the MTCA.

12.3 COST EFFECTIVENESS

Composting and incineration were the two alternatives capable of achieving the RAOs. The present worth cost of composting (\$916,000) is nearly 40 percent less than that of incineration (\$1,499,000). The selected remedy provides an overall effectiveness proportional to costs and represents a reasonable value for the money that will be spent.

12.4 UTILIZATION OF PERMANENT SOLUTIONS AND ALTERNATIVE TREATMENT TECHNOLOGIES OR RESOURCE RECOVERY TECHNOLOGIES TO THE MAXIMUM EXTENT PRACTICABLE

The selected remedy represents the best balance of tradeoffs among the alternatives evaluated. It provides a high degree of permanence; uses innovative treatment technologies to the maximum extent practicable, does not negatively affect human health or the environment during remediation, can be completed in a reasonable length of time, and is cost effective.

The selected remedy was chosen primarily because it complies with MTCA, an applicable regulation, and is the most cost-effective means of achieving the RAOs.

The selected remedy meets the statutory requirement to use permanent solutions to the maximum extent practicable. Composting of soil from Site D will permanently destroy ordnance compounds.

12.5 PREFERENCE FOR TREATMENT AS PRINCIPAL ELEMENT

The preference for treatment as a principal element of the remedial action is satisfied at Site D by using composting, an innovative treatment technology, to permanently destroy the highest concentrations of ordnance compounds in soils.

13.0 DOCUMENTATION OF SIGNIFICANT CHANGES

No significant changes from the final feasibility study or proposed plan have occurred in preparing the ROD.

14.0 REFERENCES

- Chan, E., et al. 1982. "The Use of Wetlands for Water Pollution Control." Associated Bay Area Gouch., LA. PB83-107466.
- Greeson, P.E., J.R. Clark, and J.E. Clark (eds.). 1979. *Wetland Functions and Values: The State of our Understanding*. Proceedings of the American Water Resources Association.
- Hart Crowser. 1989. *Current Situation Report, Sites C, D, E, F, 5, 6, 11, 12, 24 and 25, SUBASE, Bangor. Washington.*
- Metro (Municipality of Metropolitan Seattle). 1982. "Toxicants in Urban Runoff." Metro Toxicant Report No. 2. Seattle, Washington.
- United States Environmental Protection Agency (U.S. EPA). 1992. *Dermal Exposure Assessment: Principles and Applications*. EPA/600/8-91/011 B. Office of Health and Environmental Assessment, Washington, D.C. January 1992.
- . 1991a. *Supplemental Risk Assessment Guidance for Superfund*. Region 10, Seattle, Washington.
- . 1991b. *Executive Order 11990, Protection of Wetlands*, 40 CFR 6. U.S. EPA, Washington, D.C.

SUBASE, BANGOR OPERABLE UNIT 6
U.S. Navy CLEAN Contract
Engineering Field Activity, Northwest
Contract No. N62474-89-D-9295
CTO 0039

Record of Decision
Date: 07/19/94
Page 91

-----, 1989. *Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual.* EPA/540/1-89/002, Office of Emergency and Remedial Response, U.S. EPA, Washington, D.C.

-----, 1986. *Ecological Risk Assessment.* EPA/540/9-85/001, Office of Pesticide Programs, Washington, D.C.

United States Navy (U.S. Navy). 1983. *Initial Assessment Study of Naval Submarine Base Bangor, Bremerton, Washington.* NEESA 13-004.

URS Consultants, Inc. (URS). 1993. *Final Remedial Investigation/Feasibility Study. Operable Unit 6, Naval Submarine Base, Bangor, Washington.* CTO 0039. December 1993.

Washington State Department of Ecology (Ecology). 1991. *Project-Level Guidance Document for Addressing Environmental Protection Under the Model Toxics Control Act Cleanup Regulations (Chapter 173-340 WAC).* Olympia, Washington. October 1991 Draft.

Weston, Roy F., Inc. 1993. *Windrow Composting Demonstration for Explosives—Contaminated Soils at the Umatilla Depot Activity, Hermiston, Oregon.* Prepared for U.S. Army Environmental Center (USAEC), Report No. CETHA-TS-CR-93043. August 1993.

Attachment 1

RESPONSIVENESS SUMMARY

Attachment 1

RESPONSIVENESS SUMMARY

This Responsiveness Summary addresses the public comments received on the proposed plan for remedial action at OU 6 (Site D) at SUBASE, Bangor. Two comments were received during the public comment period of January 9, 1994, through February 8, 1994. The comments were received at a public meeting held by the Navy on January 27, 1994, at the Olympic View Community Club in Silverdale, Washington.

1.0 SUMMARY OF PUBLIC COMMENT

Two comments were received by the Navy concerning the proposed plan. These were oral comments raised at and responded to during the public meeting. A transcript of the public meeting is available at the information repositories.

Summary of Comments: Two members of a community organization stated that the organization had reviewed technical documents regarding the proposed plan. The organization agreed with the proposed plan and believed the Navy had done a good job during the investigations. The members thanked the Navy for the opportunity to participate in the process and expressed interest in remaining involved in the development of the monitoring program and its results.

2.0 RESPONSE TO COMMENT

Response: The Navy appreciates the comment regarding the quality of the documents and investigations. The Navy encourages and values public participation in this process.